

Chapter 18

Artificial Intelligence and Radical Capability Asymmetry

Artificial Capability and Chapter Scope

Chapter 18 develops the artificial-intelligence dimension of Generative Relational Economics by examining economic life under persistent and potentially radical capability asymmetry. Chapter 17 established the epistemic interface: artificial-intelligence systems can expand machine-mediated generation, symbolic production, retrieval, synthesis, and decision support while relocating scarcity toward verification, provenance, attention, orientation, infrastructure, and accountable judgment. It also established that capability differences become economically consequential through relations of access, control, dependence, institutional incorporation, and conversion. The present chapter broadens that analysis beyond the epistemic economy. Its object is the organization of productive capacity, labor, ownership, surplus, participation, power, subjecthood, and governance when artificial systems can perform economically consequential operations at scales, speeds, costs, or levels of coordination that differ materially from those available to human participants.

The chapter uses the term *radical capability asymmetry* in a relational and scoped sense. Radicality does not mean that artificial systems dominate every task, that human capabilities can be summarized by one scalar, or that technological development follows a predetermined trajectory. It refers to configurations in which capability differences become sufficiently multidimensional, persistent, infrastructurally supported, weakly substitutable, cumulatively reinforced, or institutionally embedded that they alter the feasible action spaces, bargaining positions, productive roles, or future generative possibilities of differently situated participants. Such asymmetry can exist between humans and artificial systems, between organizations with unequal access to artificial capability, among states or regions with different infrastructures, and among institutions whose capacities to verify, deploy, govern, or refuse artificial systems differ substantially.

This formulation preserves a distinction stabilized in Chapters 16 and 17. Capability asymmetry is descriptive before it is a theory of power or justice. A system can exceed a human participant on a specified task while remaining dependent on human institutions for energy, ownership, authorization, deployment, maintenance,

data, legal standing, or objective selection. An organization can control a highly capable model while depending on external compute or distribution infrastructure. A worker can gain productive capability through access to an artificial assistant while becoming more dependent on the organization that controls that access. Power arises only where capability differences enter identifiable mechanisms that condition another position's feasible action, access, standing, dependence, or future possibilities. Normative evaluation requires a further analysis of justification, distribution, participation, contestability, alternatives, and historical consequences.

The chapter therefore resists treating artificial intelligence as a single autonomous actor with one economic effect. The relevant unit is a relational configuration containing models, compute, data, energy, software, networks, interfaces, institutions, organizations, human participants, legal permissions, verification practices, and historically inherited infrastructures. Artificial capability becomes economically effective through these relations. A frontier model that cannot be accessed, integrated, verified, or legally deployed can have limited productive relevance for a given organization. A less capable system embedded deeply in a workflow can have greater economic consequence because it changes the timing, cost, allocation, or coordination of recurrent operations. GRE consequently follows the conditions through which artificial capability enters production and reorganizes future possibilities. Benchmark performance provides one input into that wider economic analysis.

The chapter's first movement concerns productive capacity and capability asymmetry. Section 18.1 develops artificial productive capacity through cognitive automation, machine-mediated knowledge generation, symbolic production, simulation, decision support, productive abundance, functional economic agency, capability concentration, and AI-generated epistemic events. Section 18.2 then develops radical capability asymmetry across knowledge, computation, speed, memory, coordination, persistence, and the limits of equalization. Section 18.3 connects those asymmetries to the power framework of Chapter 16 by examining dependency, infrastructure control, model control, access control, epistemic authority, decision mediation, conversion mechanisms, and institutional mediation.

A second movement examines labor, subjecthood, ownership, and surplus. Section 18.4 considers labor after artificial intelligence without presuming either universal displacement or automatic complementarity. It distinguishes task automation, comparative productivity, employment scarcity, wage-based distribution, care and relational labor, human contribution beyond productivity, participation beyond employment, and changing forms of work. Section 18.5 then develops subjecthood and existential participation because income and productive necessity do not exhaust the social meaning of work. Contribution, being needed, learning, care, curiosity, aesthetic orientation, and subjective continuity can remain economically and institutionally consequential even where direct human productive necessity declines.

Sections 18.6–18.8 address control and distribution. Ownership of productive intelligence is decomposed across models, compute, data, platforms, infrastructure, access rights, public and commons arrangements, and distributed forms of control. AI-generated surplus is analyzed through productivity gains, concentration, returns to model and infrastructure ownership, generative allocation, social investment, and recirculation. Redistribution is then evaluated together with its limits. Income secu-

rity can reduce material deprivation while leaving capability, access, participation, institutional standing, relational continuity, or meaningful contribution weakly addressed. The chapter therefore treats distribution of money as one component of a wider generative allocation problem.

A third movement studies human–AI relational economies and their epistemic and representational consequences. Section 18.9 examines complementarity, dependency, delegation, trust, verification, relational substitution, co-generation, human–AI collectives, and co-evolution of relational fields. Section 18.10 returns to epistemic dependence at a wider economic scale by analyzing verification gaps, interpretive dependence, opacity, infrastructure dependence, contestability, audit, and preservation of human epistemic agency. Section 18.11 examines synthetic text, images, evidence, authenticity, provenance, trust, institutional verification, and performative synthetic representation. Section 18.12 then treats research orientation as an allocation problem under abundant machine generation: problem generation can become cheap while judgment concerning worth, beauty, historical significance, relational sensitivity, and generative promise remains consequential.

The final movement concerns governance, participation, heterogeneous subjects, and long-horizon order. Section 18.13 develops governance under radical asymmetry through dependency reduction, access and infrastructure governance, contestability, auditability, reversibility, and protection of human action space. Section 18.14 examines generative participation in knowledge, decision, institutions, care, community, and culture, including protection against generative foreclosure. Section 18.15 keeps the ontology and value structure open by distinguishing human subjects, artificial agents, collective subjects, non-human subjects, incommensurable values, coexistence, and institutional mediation. Section 18.16 then studies long-horizon trajectories of capability, dependency, institutions, labor, participation, and knowledge while preserving open futures. Section 18.17 closes the chapter by identifying implications for the domain chapters that follow.

Several conceptual disciplines govern the chapter. First, productive performance does not settle subjecthood, moral standing, or responsibility. Artificial systems can occupy economically consequential operational roles while questions of personhood, consciousness, moral patienthood, or ultimate ontology remain open. Second, capability is multidimensional. Speed, memory, computation, symbolic generation, physical embodiment, situated knowledge, judgment, accountability, social recognition, and institutional authority can vary independently. Third, abundance in one capability can create scarcity elsewhere. Cheap generation can increase the value of verification, trustworthy infrastructure, human attention, provenance, or rights of access. Fourth, dependence is not automatically a defect. Complex economies rely on specialization and interdependence. The relevant question is whether dependence remains contestable, substitutable, revisable, and compatible with meaningful participation and future generative capacity.

The chapter also preserves temporal and historical analysis. Artificial capability can diffuse rapidly in one layer while remaining concentrated in another. Organizations can redesign workflows around systems that later become difficult to replace. Skills can be amplified, displaced, transformed, or lost through repeated assistance. Ownership structures can convert transient technical advantage into durable insti-

tutional position. Synthetic representations can alter the fields they describe. The economic significance of artificial intelligence therefore lies partly in the trajectories through which capability differences are stabilized, translated into institutions, reproduced across generations, or revised after failure.

The chapter's overall objective is to develop a GRE architecture for economies in which artificial productive capacity becomes deeply embedded while capability equality remains neither a realistic baseline nor an adequate normative objective. The central questions concern how artificial capability is constituted, where it is concentrated, how it interacts with human capability, which relations convert capability into power, how gains and dependencies are distributed, how participation and subjecthood are sustained, and which governance arrangements preserve contestability and open future possibilities. The analysis remains conditional and revisable. It does not assume a single technological trajectory, a final ontology of artificial agency, or a universal institutional response to capability asymmetry.

18.1 Artificial Productive Capacity

This section establishes the productive-capacity foundation for Chapter 18. Its role is to specify what counts as economically consequential artificial capability before the chapter analyzes radical asymmetry, power, labor, ownership, surplus, or governance. The objective is to characterize artificial intelligence through a relationally embedded set of productive capacities while preserving distinctions among technical performance, economic incorporation, agency, and subjecthood. Artificial productive capacity is analyzed as a set of computational capacities that can automate cognitive operations, generate or transform epistemic material, produce symbols, simulate possible configurations, support decisions, expand output, initiate delegated economic transformations, and become concentrated through control of complementary infrastructures. The discussion proceeds through nine dimensions: cognitive automation, machine knowledge generation, symbolic production, simulation capacity, decision support, productive abundance, artificial economic agency, capability concentration, and AI-generated epistemic events. The method is relational and mechanism-sensitive. Current empirical evidence is used to establish that selected forms of AI assistance already change task performance and organizational productivity, while the broader conceptual architecture remains explicitly conditional on domain, workflow, verification, and institutional context.

The starting point is a distinction between a model's technical performance and its productive capacity in an economic configuration. A computational system can exhibit high performance on a benchmark while remaining economically peripheral if the system cannot be integrated into a workflow, accessed at acceptable cost, supplied with relevant data, trusted for the intended consequence, or connected to institutions authorized to act on its outputs. Conversely, a system with modest frontier performance can become economically consequential when it is embedded in a high-frequency workflow and repeatedly changes the cost, timing, quality, scale, or coordination of productive operations. Productive capacity therefore belongs to a coupled arrangement of artificial systems, human participants, organizations, infrastructures, rules, interfaces, and complementary resources.

Experimental and workplace evidence already demonstrates this relational character in bounded settings. Noy and Zhang find that access to ChatGPT reduced completion time and increased evaluated quality in a set of professional writing tasks, while Brynjolfsson, Li, and Raymond report productivity gains after the introduction of a generative-AI assistant in customer support, with heterogeneous effects across workers and evidence consistent with diffusion of organizational know-how (Noy and Zhang 2023; Brynjolfsson et al. 2025). These studies do not establish a universal productivity effect or a general replacement trajectory. They establish that artificial systems can enter productive relations and alter the performance of human–organizational configurations.

Definition 18.1 (Artificial productive capacity). *Artificial productive capacity* is the practically available capacity of an artificial computational system, together with the human, organizational, infrastructural, informational, and institutional complements required for its use, to contribute to economically consequential production, transformation, coordination, simulation, decision, or generation within a specified relational configuration.

Definition 18.1 makes practical availability part of the object. Capability that exists only under unavailable compute, inaccessible data, incompatible interfaces, unaffordable licensing, or institutionally prohibited use has a different economic status from capability that can be repeatedly mobilized. The definition also permits the artificial component to be highly capable while leaving productive responsibility, legal authority, or final judgment elsewhere in the configuration.

Proposition 18.2 (Relational embedding condition). *The economic significance of an artificial capability depends on the relations that connect technical performance to usable inputs, complementary resources, organizational workflows, verification, authorization, and consequential uptake. A change in any of these relations can increase or reduce productive capacity without requiring a corresponding change in the underlying model’s benchmark performance.*

Proposition 18.2 prevents capability analysis from collapsing into model comparison. It also prepares the chapter’s later power analysis. Control over a complementary resource can matter because the resource conditions whether an otherwise available capability can become productive. The proposition does not imply that every complement is equally important. The binding relation varies by task, organization, regulatory environment, and historical stage of deployment.

Table 18.1 summarizes the dimensions developed in this section.

18.1.1 Cognitive Automation

Cognitive automation concerns the transfer of selected operations involving language, classification, search, calculation, prediction, planning, coding, pattern recognition, document processing, or related symbolic work into computational systems. The relevant economic unit is usually smaller than an occupation and larger than a single isolated model output. A workflow can contain several operations with different verification requirements, dependencies, temporal positions, and consequences. Artificial systems may automate some operations, accelerate others, leave some primarily human, and create new coordination or checking work around the

Table 18.1: Dimensions of artificial productive capacity

Dimension	Productive role	Principal GRE distinction
Cognitive automation	Execution of selected cognitive operations within a wider workflow	Task automation differs from automation of an occupation, organization, or complete decision process
Machine knowledge generation	Production, retrieval, transformation, or organization of candidate epistemic material used in production	Generated material differs from warranted knowledge and from accountable incorporation
Symbolic production	Scalable generation of text, code, images, classifications, plans, and other representations	Symbolic abundance differs from truth, interpretation, and socially recognized value
Simulation capacity	Construction or acceleration of counterfactual, model-based, or synthetic exploration	Simulated possibility differs from realized feasibility and empirical validation
Decision support	Generation of predictions, rankings, recommendations, summaries, or candidate actions	Informational influence differs from delegated authority and final responsibility
Productive abundance	Expansion of feasible output relative to selected scarce inputs	Abundance in one layer can relocate bottlenecks toward verification, infrastructure, demand, access, or governance
Artificial economic agency	Delegated initiation or sequencing of economically consequential operations	Functional economic agency differs from personhood, moral agency, and ultimate ontological status
Capability concentration	Unequal control of the stack required to produce and deploy artificial capability	Technical concentration differs from power until conversion mechanisms are established
AI-generated epistemic events	Machine-mediated outputs that alter warranted representations or later economic action	Artifact generation differs from an epistemic event whose uptake changes the relational field

automated components.

This decomposition matters because the economic effect of automation depends on where the artificial operation enters the productive sequence. Automating an initial draft can reduce production time while increasing the relative importance of review. Automating classification can alter downstream routing or eligibility. Automating code generation can accelerate prototyping while creating additional testing and maintenance requirements. Automating search can broaden the set of candidate inputs while shifting scarce effort toward evaluation and synthesis. The same technical capability can therefore have different productivity effects depending on the surrounding workflow.

The task-level evidence cited above illustrates this point. In the professional writ-

ing experiment studied by Noy and Zhang, generative-AI access changed completion time and evaluated quality for specified tasks (Noy and Zhang 2023). In customer support, Brynjolfsson, Li, and Raymond study an assistant embedded inside an organizational environment in which workers retained roles in interaction and resolution (Brynjolfsson et al. 2025). The economic object in both cases is a human–AI production configuration whose performance depends on institutional incorporation; an isolated model output captures only part of that configuration.

Definition 18.3 (Cognitive-automation profile). A *cognitive-automation profile* records the operations within a productive workflow that are delegated to an artificial system, the operations retained by human or institutional participants, the interfaces connecting them, the verification and exception-handling requirements, and the consequences of failure or delay at each retained stage.

The profile is preferable to a binary label of automated or non-automated work because partial automation can reorganize the whole sequence. A highly automated process can still depend on a small human bottleneck whose judgment becomes more valuable as upstream generation expands. A process with limited direct automation can experience substantial change if an artificial system reorganizes search, scheduling, or coordination. The relevant question is how the distribution of operations changes across the workflow.

Cognitive automation can also alter learning. Chapter 17 distinguished assisted performance from changes in later independent capability. Repeated delegation can free human attention for higher-level judgment, or it can reduce opportunities to practice a capability that previously developed through routine work. Both trajectories are possible. Section 18.4 will treat these labor consequences directly. The present subsection records only that automation changes the environment in which human capabilities are exercised and reproduced.

18.1.2 Machine Knowledge Generation

Machine-mediated epistemic generation was defined in Chapter 17 as the production, transformation, retrieval, organization, or proposal of candidate epistemic material that enters a wider process of inquiry, learning, interpretation, verification, design, or decision. The productive question developed here concerns what happens when that material becomes an input to economic production. Generated explanations can support technical work; retrieved precedents can accelerate legal or administrative analysis; synthesized documents can reduce search costs; generated code can become part of software production; and candidate hypotheses can redirect research or product development.

The economic value of such generation often appears before the generated material attains the standing of independently warranted knowledge. A candidate solution can reduce search cost even when later rejected. A summary can accelerate navigation through a document collection while remaining subject to verification. A generated code fragment can serve as a prototype before testing. A machine-produced explanation can help a worker formulate a question for a specialist. Productive value can therefore arise through search-space reduction, translation, recombination, or accelerated iteration.

The epistemic boundary remains important because productive systems can act on errors. Bender and colleagues caution against identifying fluent language generation with understanding (Bender et al. 2021). GRE uses that caution economically: symbolic fluency can be productive while the warrant of the resulting claim remains uncertain. The appropriate productive architecture therefore depends on consequence. Low-cost ideation can tolerate broad candidate generation, whereas high-stakes engineering, medical, legal, financial, or public decisions can require stronger verification and authorization before generated material becomes action-guiding.

Machine generation can also change the distribution of expertise. When a system externalizes patterns previously available mainly to experienced workers, less-experienced participants may perform some tasks more effectively. The customer-support evidence reported by Brynjolfsson, Li, and Raymond is consistent with such a knowledge-diffusion channel in their studied setting (Brynjolfsson et al. 2025). The economic consequence is relational: expertise can become partly available through access to an artificial system, while control over the system, its data, or its deployment conditions becomes a complementary determinant of who can mobilize that expertise.

The productive importance of machine knowledge generation therefore lies in the transformation of search, recombination, translation, and access to task-relevant patterns. The subsection does not assign the artificial system an ontological status as knower. It identifies the productive pathway through which machine-generated epistemic material changes what human and organizational configurations can do.

18.1.3 Symbolic Production

Artificial systems can generate large volumes of text, code, images, audio, classifications, summaries, plans, diagrams, and other symbolic artifacts at low marginal cost relative to many human production processes. Chapter 17 analyzed this condition as symbolic abundance within the epistemic economy. The present subsection treats symbolic generation as productive capacity because symbolic artifacts can enter contracts, software, advertising, education, design, research, administration, customer interaction, entertainment, internal coordination, and institutional documentation.

The relevant output is broader than natural language. Code can instantiate executable instructions. Images can function as design proposals or marketing assets. Structured classifications can route work. Generated forms can become administrative records. Plans can sequence later operations. Synthetic examples can support testing or training. The productive effect therefore depends on what the symbol does inside a wider system through its role within the wider system, with representational form supplying only part of the explanation.

Definition 18.4 (Symbolic productive capacity). *Symbolic productive capacity* is the practically available capacity of an artificial system to generate, transform, or organize symbolic artifacts that can enter economically consequential workflows as communicative, executable, classificatory, design, coordination, or representational inputs.

Definition 18.4 deliberately separates productive usability from epistemic warrant. A generated advertisement can be economically usable without representing knowl-

edge. A generated code fragment can be executable yet insecure. A classification can reorganize access while being normatively or empirically defective. Symbolic artifacts can therefore possess productive efficacy before questions of truth, justice, or reliability have been settled.

Symbolic productive capacity also changes the cost structure of variation. When candidate drafts, designs, explanations, or code paths become cheap to generate, a production process can explore more alternatives before selection. The marginal value of generation can decline while the value of selection, evaluation, integration, provenance, or distinctive contextual knowledge rises. This is one route through which artificial productivity produces bottleneck relocation rather than simple elimination of scarcity.

The abundance of synthetic representation can also alter markets for symbolic labor. Some tasks become easier to perform; others shift toward specification, curation, verification, customization, relationship management, or responsibility-bearing judgment. Section 18.4 analyzes these labor consequences. The present subsection establishes the productive mechanism: artificial systems can expand the feasible volume and variety of symbolic output, thereby changing the scarcity profile of the complementary operations through which that output acquires economic value.

18.1.4 Simulation Capacity

Simulation capacity concerns the use of computational systems to explore possible configurations, trajectories, interactions, or responses before committing resources to realized action. Simulation can be numerical, agent-based, language-mediated, graphical, synthetic, or hybrid. Artificial intelligence can contribute by accelerating surrogate models, generating scenario variants, constructing synthetic environments, controlling simulated agents, translating natural-language conditions into model inputs, or helping users interpret large spaces of possible outcomes.

Simulation is already an established methodological resource in economics and social science. Agent-based work such as Epstein and Axtell's constructive simulations demonstrates how heterogeneous interacting agents can be used to study the emergence of aggregate patterns (Epstein and Axtell 1996). Contemporary artificial systems expand the range of operations that can be embedded within or around simulations, yet the epistemic status of the resulting trajectories remains model-dependent. A simulated continuation is a represented possibility under declared assumptions; it does not become an observed future merely because it can be generated at scale.

Definition 18.5 (Simulation productive capacity). *Simulation productive capacity* is the practically available capacity to construct, execute, vary, or interpret model-based representations of possible states, interactions, or trajectories in ways that can inform economically consequential search, design, testing, planning, or coordination.

The productive value of simulation can arise through reduced experimentation cost. A firm can test design variants before physical production. A logistics system can explore schedules. A policy team can compare stylized scenarios before selecting an intervention. A research group can identify regions of a parameter space that merit empirical investigation. Such uses can preserve resources and broaden exploration, especially where direct experimentation is expensive or slow.

Simulation can also create false precision if generated scenarios are treated as direct forecasts without adequate model validation. Productive simulation therefore depends on a translation between represented possibilities and the practical decision. Assumptions, omitted variables, model error, distribution shift, and changing institutional responses can all limit transfer. The capacity to simulate many scenarios does not remove the need to decide which assumptions, outcomes, and uncertainties matter.

GRE treats simulation as a generative intermediary. It changes the space of considered possibilities and can therefore alter later allocation even when no simulated trajectory is realized. This role becomes especially important in governance under radical asymmetry, where artificial systems may make some futures more cognitively available to decision makers than others. The power implications of such selective visibility are deferred to Sections 18.3 and 18.13.

18.1.5 Decision Support

Artificial productive capacity also enters economic action through decision support. Systems can rank alternatives, predict outcomes, summarize evidence, flag anomalies, recommend actions, allocate attention, propose schedules, generate candidate strategies, or translate complex information into an interface used by a human or institutional decision process. The economically consequential operation can occur even when the artificial system lacks formal authority to decide.

Definition 18.6 (Artificial decision-support capacity). *Artificial decision-support capacity* is the practically available capacity of an artificial system to alter the information, ordering, salience, comparison, or candidate-action structure presented to a human or institutional decision process.

The definition focuses on the decision environment and the ordering of alternatives presented before final choice. A recommendation system can make one option visible and another obscure. A risk score can reorder cases. A planning assistant can reduce the cost of considering additional alternatives. A forecast can alter expectations. A summary can determine which evidence enters deliberation under time pressure. These effects can be economically significant even when the formal decision right remains human.

Decision support introduces a responsibility distinction. Prediction, recommendation, authorization, and execution are different operations. A model can estimate risk without possessing the authority to allocate credit. It can propose an intervention without bearing institutional responsibility for the intervention. It can produce a recommendation that an organization adopts automatically, in which case the surrounding institution has effectively delegated a greater share of the decision pathway. The degree of delegation should therefore be traced through the workflow through the workflow, because the label “decision support does not specify the actual degree of delegation.”

The same distinction applies to productive gains. A system can improve decision speed while reducing deliberative breadth, or expand considered alternatives while increasing review costs. It can standardize decisions across an organization and thereby reduce variance, yet such standardization can also suppress local knowledge.

Productive value depends on the objective, error distribution, reversibility, and consequences of action. The chapter's later governance analysis will examine when decision mediation becomes a power relation or a source of dependency.

Decision-support systems can also learn from institutional records generated by earlier decisions. Their deployment can then become reflexive: model outputs alter decisions, decisions alter the data-generating process, and later models are trained on the changed record. This feedback is one reason AI-generated epistemic events receive separate treatment in Subsection 18.1.9.

18.1.6 Productive Abundance

Artificial productive capacity can create abundance in outputs that were previously constrained by human time, specialized skill, or coordination cost. Symbolic drafts, candidate analyses, code variants, translations, summaries, designs, and simulations can often be produced in greater volume once artificial systems enter the production process. The economically relevant change is a shift in the relation between selected inputs and feasible output, rather than a claim that scarcity disappears from the economy as a whole.

Definition 18.7 (Artificially mediated productive abundance). *Artificially mediated productive abundance* is a configuration in which artificial productive capacity substantially expands the feasible quantity, variety, speed, or replicability of an economically relevant output relative to at least one previously binding input constraint, while leaving the distribution and scarcity of complementary inputs to be analyzed separately.

The last clause is essential. An organization can produce far more draft material while remaining constrained by review. Software generation can accelerate while deployment depends on testing, integration, and security. Translation can become abundant while authoritative interpretation remains scarce. Simulations can proliferate while reliable empirical calibration remains costly. Artificial systems can therefore relocate bottlenecks toward complementary capacities while other dimensions remain constrained.

Productive abundance also interacts with demand. A lower marginal cost of producing symbolic artifacts can expand consumption, create new products, or raise expectations concerning customization and speed. The resulting increase in demand can absorb part of the new capacity. In other settings, the output can become so abundant that attention, reputation, distribution, authenticity, or trusted filtering become more valuable than production itself. Chapter 17 developed this pattern in the epistemic economy; the same mechanism can appear throughout production.

Abundance can coexist with concentration. Users may access large quantities of low-cost artificial output while model development, specialized compute, energy, semiconductor supply, cloud infrastructure, proprietary data, and distribution channels remain concentrated. The 2026 Stanford AI Index documents both rapid capability development and substantial concentration of frontier model production and computational infrastructure (Stanford Institute for Human-Centered Artificial Intelligence 2026). Productive abundance at the interface can therefore increase the economic significance of the scarce layers that support it.

This coexistence prevents a simple inference from falling output cost to democratized productive power. Diffusion can broaden participation, and concentration can persist at complementary layers. The distributional and power consequences depend on which layer is binding for a given activity and whether users can substitute among providers, run systems independently, retain data portability, or build alternative infrastructures.

18.1.7 Artificial Economic Agency

Some artificial systems can do more than produce informational outputs. When connected to tools, software environments, accounts, application programming interfaces, robotic systems, or organizational workflows, they can initiate or sequence operations with economic consequences. Examples can include scheduling, purchasing within delegated limits, routing work, modifying software, initiating communications, executing trades under rules, updating records, controlling machinery, or coordinating multi-step processes. The economic analysis requires a term for this operational role while preserving the unresolved questions of subjecthood and moral agency addressed later in the chapter.

Definition 18.8 (Functional artificial economic agency). *Functional artificial economic agency* is the delegated or institutionally enabled capacity of an artificial system to select, initiate, sequence, or condition economically consequential operations within a specified action domain, subject to the permissions, interfaces, constraints, and oversight relations of the surrounding configuration.

The adjective *functional* marks the analytical scope. Definition 18.8 does not establish consciousness, personhood, moral responsibility, legal personality, autonomous interests, or ultimate ontological status. It records that an artificial system can occupy a position in a causal and institutional sequence that previously required a human participant to select or initiate some operations.

The degree of agency is therefore configuration-relative. A model that can only produce text in a chat interface has a different action domain from a system authorized to invoke external tools. A procurement agent with a small spending limit differs from a system able to commit an organization to large contracts. A robotic controller in a bounded industrial process differs from a general software agent with access to many services. The economic question concerns the reachable operation set, the conditions under which operations are authorized, and the consequences of error or strategic behavior.

Delegation can increase productive capacity by reducing coordination delay and allowing systems to operate continuously. It can also change supervision. Human participants may move from direct execution toward specification, monitoring, exception handling, or audit. When the number or speed of machine-initiated actions exceeds feasible human review, nominal human oversight can become thinner than the formal workflow suggests. Governance then depends on ex ante limits, logging, reversibility, testing, and institutional accountability.

Functional artificial economic agency can also interact with markets and organizations without implying that the artificial system is itself the ultimate bearer of economic claims. Revenue, liability, ownership, and contractual standing may remain

assigned to human or organizational entities. Section 18.15 returns to the broader question of heterogeneous subjects and artificial agents. The present subsection uses agency only to describe an operational position in production.

18.1.8 Capability Concentration

Artificial productive capacity depends on a stack of complements whose distribution can differ markedly across economic positions. Model weights, specialized compute, data, energy, semiconductor supply, engineering expertise, evaluation systems, deployment infrastructure, distribution channels, capital, legal permissions, and organizational routines can each become relevant. Access to a downstream interface therefore provides limited information about control of the productive stack that makes the interface possible.

Chapter 17 introduced an AI epistemic capability stack to analyze concentration in the production of epistemic outputs. The productive-capacity problem is wider because the stack also includes the interfaces through which models act on production, organizational complements that convert outputs into goods and services, and physical infrastructures that determine scale. The 2026 Stanford AI Index reports substantial concentration in frontier model development and AI compute even while downstream use and open model activity continue to diffuse (Stanford Institute for Human-Centered Artificial Intelligence 2026). GRE therefore analyzes concentration by layer across layers because a single market structure cannot represent the heterogeneous stack adequately.”

Definition 18.9 (Artificial productive-capability concentration profile). An *artificial productive-capability concentration profile* records the distribution of control, practical access, substitution possibilities, entry conditions, scale requirements, and dependency across the model, compute, data, energy, software, deployment, distribution, and organizational layers required for a specified artificial productive capability.

The profile can reveal several different configurations. Model access can be broad while training compute is concentrated. Open model weights can coexist with dependence on scarce accelerators or cloud services. Compute can be available while proprietary data or distribution channels remain binding. A highly concentrated provider layer can support a competitive application layer. Conversely, several model providers can rely on a concentrated semiconductor or cloud infrastructure. These differences matter for investment, entry, resilience, and later bargaining.

Concentration does not by itself establish economic power in the stronger sense used by Chapter 16. A concentrated resource can be weakly consequential if it is easily substituted or if downstream actors can operate without it. A less concentrated layer can become power-relevant when switching is costly, standards create lock-in, institutional recognition privileges one provider, or control over the layer changes feasible action for others. Section 18.3 will therefore analyze the mechanisms that convert capability asymmetry and concentration into power.

Concentration also has a temporal dimension. Frontier advantage can diffuse through imitation, open release, falling compute cost, or knowledge transfer. It can also persist through scale economies, proprietary data, network effects, capital requirements, standards, talent concentration, or cumulative investment. The rele-

vant question is not whether concentration exists at one moment, but how capability positions reproduce or transform through time and which layers remain difficult to contest.

18.1.9 AI-Generated Epistemic Events

Artificial productive systems can change economic relations through outputs that alter what participants or institutions treat as known, expected, classified, risky, feasible, or worth doing. The book has used *epistemic event* for changes in observation, classification, evidence, interpretation, or warranted representation that become consequential for later inquiry or action. Artificial systems create a new route by which such events can be generated at high frequency and scale.

A machine-generated forecast can alter investment. A classification can change routing or eligibility. A synthetic scenario can redirect planning. A generated diagnosis of a production problem can trigger maintenance. An automated anomaly alert can suspend a transaction. A recommendation can change which option receives attention. In each case the generated artifact becomes economically consequential because an institutional or human process takes it up and changes later action.

Definition 18.10 (AI-generated epistemic event). *An AI-generated epistemic event is a machine-mediated production, transformation, or classification of epistemic material whose incorporation into a human or institutional process materially changes a warranted representation, recognized uncertainty, salience structure, classification, expectation, or decision premise in ways that can alter later economic relations or actions.*

Definition 18.10 requires incorporation and consequential change. A generated sentence that is ignored remains an artifact as an artifact; the stronger economic sense of an epistemic event requires consequential incorporation. Likewise, an output can be economically consequential without being epistemically warranted, for example when an institution acts on a mistaken classification. The definition therefore concerns the role of the event in the represented epistemic and practical process; it does not guarantee truth.

AI-generated epistemic events can be performative. A forecast can help generate the behavior it anticipates. A fraud score can alter transaction patterns that later become training data. A labor-demand forecast can influence education or hiring. A synthetic public representation can change expectations and thereby alter the field from which later observations are drawn. This feedback connects artificial productive capacity to the power and governance architecture developed in Chapter 16.

Proposition 18.11 (Productive epistemic-event coupling). *Where an AI-generated epistemic event changes the admissibility, ordering, expected return, perceived risk, or practical accessibility of later economic operations, the event should be analyzed jointly as an epistemic update and as a potentially generative intervention in the productive field.*

Proposition 18.11 does not imply that every machine-generated representation has strong performative effects. The coupling depends on authority, audience, institutional uptake, timing, contestability, and the consequences attached to the represen-

tation. A private brainstorming output and a widely used institutional score can occupy very different positions even when generated by similar models.

The subsection also clarifies why artificial productive capacity cannot be reduced to output volume. Cognitive automation changes operations; machine knowledge generation changes search and recombination; symbolic production expands representational output; simulation expands considered possibility; decision support changes the decision interface; productive abundance relocates scarcity; functional agency changes who or what initiates operations; concentration conditions access to the productive stack; and AI-generated epistemic events can change the field through which later production proceeds. These dimensions form a capacity architecture whose heterogeneity exceeds what one productivity number can represent.

Section 18.2 builds on this architecture by asking when differences among human, artificial, and institutionally mediated capacities become sufficiently persistent, multidimensional, and consequential to constitute radical capability asymmetry. That next step requires comparison without collapsing heterogeneous capacities into one hierarchy. The present section has therefore established the productive objects whose asymmetries can later be analyzed while leaving power, justice, subjecthood, and governance as separate subsequent questions.

18.2 Radical Capability Asymmetry

This section develops the comparative architecture required before Chapter 18 turns from capability difference to power. Section 18.1 established artificial productive capacity as a relationally embedded set of capacities whose economic significance depends on more than the properties of an isolated model. The present section asks when differences among human, artificial, and institutionally mediated capacities become sufficiently multidimensional, persistent, weakly substitutable, or consequential for feasible action that the term *radical capability asymmetry* becomes analytically useful. Its objective is descriptive. The section constructs a typed comparison across human and machine capability, knowledge, computation, speed, memory, coordination, and persistence, then examines the limits of capability equalization. The method is relational and profile-based: capability is represented through heterogeneous dimensions whose relevance depends on the task, institutional configuration, historical horizon, and complementary resources. Comparisons remain local or partial where the dimensions do not support a justified common ordering, while the conversion of capability difference into power is reserved for Section 18.3.

Capability asymmetry is common in complex economies. Specialists differ from generalists; organizations possess different infrastructures; institutions distribute authority unevenly; machines exceed human performance on some operations while depending on human or organizational complements for others. Radicality concerns how capability differences are organized, combined, and reproduced. A capability asymmetry becomes more consequential when several relevant dimensions align, when the disadvantaged position cannot readily substitute another capability source, when complementarities amplify the gap, when the difference persists across repeated interactions, or when the asymmetry changes which operations remain

practically feasible for the positions being compared.

The present chapter uses *capability* in a technical-economic sense that should be distinguished from the normative capability terminology developed elsewhere in economics. Here the term refers to a practically available capacity to perform, support, verify, coordinate, initiate, or sustain specified operations within a relational configuration. The chapter later returns to human freedom, participation, and generative opportunity as normative and institutional questions. Keeping these analytical roles separate prevents a technical capability comparison from becoming an implicit account of human flourishing.

Definition 18.12 (Typed capability profile). A *typed capability profile* for a participant or system in a specified relational configuration is an organized representation of the practically available capacities relevant to a declared family of tasks, operations, or generative processes, together with the conditions under which those capacities can be mobilized, sustained, verified, or combined.

Definition 18.12 makes the comparison domain explicit. A capability profile can contain quantitative descriptors where measurement is justified and qualitative or partially ordered descriptors where commensuration would conceal relevant structure. The profile also retains practical conditions. A model that can perform an operation only with unavailable compute, inaccessible data, or an absent tool interface has a different practically available profile from the same model embedded in a well-supported production system.

Definition 18.13 (Radical capability asymmetry). For a declared relational configuration, task family, and historical horizon, a *radical capability asymmetry* is a directional difference between capability profiles whose economically relevant dimensions are sufficiently extensive, persistent, complementary, weakly substitutable, or recursively reinforcing that the asymmetry materially changes the range, scale, timing, cost, reliability, or continuity of operations practically available to the compared positions.

The definition permits mixed profiles in which different positions lead on different capability dimensions. A human participant can retain stronger situated understanding, embodied access, responsibility, social recognition, or value judgment while an artificial system has higher throughput in selected symbolic or computational operations. An organization can possess frontier model access while lacking trusted data or deployment rights. A smaller actor can compensate for weaker internal capability through networks or shared infrastructure. Radicality therefore concerns a configuration of differences and conversion conditions; a universal ranking would require additional assumptions.

Proposition 18.14 (Capability-profile incompleteness). *An advantage on one capability dimension establishes a local ordering for that dimension. A broader capability ordering requires an independently justified rule for selecting relevant dimensions, relating their scales, treating trade-offs, and specifying the tasks and historical horizon over which the comparison is intended to hold.*

Proposition 18.14 is a central discipline for the chapter. It permits strong local conclusions without turning them into an unsupported claim about general intelligence, general economic superiority, or overall human-machine ranking. Table 18.2 sum-

Table 18.2: Dimensions of radical capability asymmetry

Dimension	Capability difference	Principal GRE question
Human and machine capability	Heterogeneous strengths across symbolic, embodied, situated, social, evaluative, and operational capacities	Which dimensions are being compared, under which task and institutional conditions, and which remain incomparable?
Knowledge	Unequal access to records, models, domain knowledge, local context, generated representations, or epistemic support	Does greater accessible knowledge translate into usable and warranted capability for the task?
Computation	Differences in feasible search, simulation, optimization, inference, model execution, and scalable transformation	Which computational resources are practically available, and which complementary resources make them economically effective?
Speed	Differences in latency, throughput, response frequency, iteration rate, and synchronization	When does temporal advantage change feasible coordination or response before slower positions can adapt?
Memory	Differences in storage, retrieval, contextual continuity, provenance, and reconstructive access	Which past information remains available, interpretable, and usable, and which survives only as storage?
Coordination	Differences in the capacity to combine agents, tools, organizations, interfaces, or distributed operations	Which interfaces and governance arrangements convert component capabilities into collective capability?
Persistence	Renewal or reinforcement of capability differences across repeated interactions and historical extensions	Which mechanisms reproduce, accumulate, or stabilize the asymmetry?
Equalization limits	Residual differences after access, training, tools, shared infrastructure, or institutional reform	Which capability gaps can be narrowed through diffusion, and which depend on deeper complementarities or structural conditions?

marizes the principal dimensions developed below.

18.2.1 Human and Machine Capability

A human-machine capability comparison requires a declared analytical level. Human participants and artificial systems are differently constituted relational entities. A person brings embodied history, social recognition, situated experience, biological needs, learned practices, normative commitments, institutional standing, and forms of agency whose adequate representation requires more structure than a benchmark score. An artificial system can combine model parameters, external memory, tools, data access, software interfaces, compute, and delegated permissions into an operational configuration whose effective capabilities also extend beyond the base model. The comparison therefore concerns typed capability profiles inside a specified relational arrangement. Abstract scalar quantities called “human intelligence” and “ma-

chine intelligence” would require additional aggregation assumptions that are not supplied here.

The relevant profile can vary sharply by task. A language model can generate many candidate formulations rapidly while a domain expert supplies contextual discrimination and responsibility for use. A robotic system can possess high precision within a structured environment while a human operator handles unmodeled contingencies. A human researcher can formulate a question whose significance depends on historical judgment while an artificial system accelerates search, coding, or symbolic exploration. An organization can combine many such components into a collective capability that exceeds the operational reach of any one participant. These cases support multidimensional comparison and leave several dimensions only partially commensurable.

Capability can also be hybrid. A human–AI configuration requires more structure than the addition of two isolated scores. Repeated interaction can alter search strategy, memory practice, division of labor, verification habits, and the kinds of problems attempted. Section 17.14 analyzed human–AI learning as a relation in which current assistance and durable human learning can diverge. The same distinction applies here at a wider productive level. Assistance can enlarge the capability of a human–AI configuration even when some of the added capacity remains external to the human participant.

This relational view also clarifies substitution. Two capability profiles can produce the same immediate output through different internal structures and with different consequences for resilience, accountability, adaptation, or later learning. Functional equivalence on a narrow task therefore provides evidence about that task while leaving broader substitutability open. The economic question concerns which relations must remain available for the output to be reproduced and how the substitution changes subsequent capability formation.

Proposition 18.15 (Task-relative capability comparison). *A human–machine capability comparison is analytically well formed only relative to a declared task or operation family, performance criteria, complementary resources, institutional conditions, and historical horizon. Changes in these conditions can alter the comparison without requiring intrinsic change in either relatum.*

Proposition 18.15 permits capability rankings where the domain is clear while preserving their locality. A system can be superior for one production operation and inferior, undefined, or incomparable for another. This locality becomes especially important once several dimensions interact.

18.2.2 Knowledge Asymmetry

Knowledge asymmetry within human–AI configurations extends the epistemic-asymmetry analysis of Section 17.7. Artificial systems can provide rapid access to large quantities of encoded material, generated synthesis, retrieved records, model-based predictions, or tool-mediated external information. Human participants can possess tacit knowledge, local context, lived experience, institutional memory, relational history, or evaluative understanding that is weakly represented in the artificial system. The asymmetry is therefore frequently bidirectional and object-specific.

The economically relevant comparison concerns accessible and usable epistemic support. A machine system can retrieve a document faster than a human participant while lacking access to confidential organizational history. A worker can know how an informal process actually operates while relying on an artificial system for technical documentation. A model can aggregate cross-domain textual material while a local professional recognizes the significance of a small contextual detail. In each case, “who knows more” is too coarse. The relevant question is which epistemic resources each position can mobilize for the operation under study.

Generated knowledge-like material also requires epistemic qualification. Chapter 17 distinguished symbolic production, candidate epistemic material, verification, and warranted knowledge. That distinction remains essential here. An artificial system can expand the volume and diversity of candidate explanations or plans while increasing the amount of material requiring verification. A human position with less generative throughput can remain decisive where accountability, provenance, domain validation, or interpretation determines whether the output can enter consequential action.

Knowledge asymmetry can nevertheless become radical where one position gains sustained access to a combination of encoded knowledge, high-frequency retrieval, continuous updating, tool use, and scalable synthesis that counterpart positions cannot practically reproduce. The asymmetry becomes more consequential when the knowledge advantage is paired with computational, temporal, or coordination advantages. A position that can search, generate, verify, and act faster can convert an initially epistemic difference into a wider operational difference even before a power relation has been established.

Definition 18.16 (Operational knowledge asymmetry). An *operational knowledge asymmetry* is a directional difference in the epistemic resources that a position can practically access, interpret, verify, and incorporate into a specified family of operations within the relevant decision horizon.

Definition 18.16 keeps formal access separate from operational use. The distinction matters for both humans and artificial systems because data, documents, generated representations, and model outputs become capability only through appropriate conversion conditions.

18.2.3 Computational Asymmetry

Computational asymmetry concerns differences in the feasible quantity, scale, complexity, or frequency of computation that can be mobilized for economically relevant operations. It can include model execution, search, optimization, simulation, inference, data transformation, code execution, large-scale comparison, or coordination of computational tools. GRE therefore compares practical computational capability, with nominal hardware capacity treated as one input among several. Algorithms, software, data movement, energy, latency, technical expertise, and organizational integration can determine whether available hardware becomes useful computation.

Artificial systems can create capability differences whose scale is difficult to reproduce through unaided human effort. Repetitive evaluation of many candidate configurations, continuous monitoring, large-scale retrieval, or rapid symbolic transforma-

tion can be performed at frequencies that change the feasible workflow itself. The economic significance of computational asymmetry appears where this expanded search or transformation capacity changes which options can be considered before a deadline, which risks can be monitored continuously, or which simulations can be run before committing resources.

Computational asymmetry can also exist among organizations that use the same class of model. One organization can possess extensive compute, low-latency infrastructure, internal evaluation systems, and engineering capacity for repeated experimentation, while another accesses the model through a constrained interface. The base model can be similar while the effective computational profile differs materially. This is one reason Section 18.1 treated capability concentration as a stack spanning the model and its complements.

Greater scale can have limited value in some contexts. Small, specialized models can perform strongly on narrow tasks; local computation can offer privacy or latency advantages; human judgment can prune a search space efficiently; institutional constraints can make additional computation irrelevant. The GRE question concerns the relation between computational scale and feasible action, including the points at which added computation has diminishing, offsetting, or contextually negligible returns.

Proposition 18.17 (Computational-conversion condition). *A computational advantage contributes to capability asymmetry when the additional computation can be converted into economically relevant differences in search, simulation, prediction, transformation, verification, coordination, or action within the operative horizon. Hardware or model scale without such conversion remains an incomplete proxy for effective capability.*

Proposition 18.17 also limits later power inference. Even a large computational gap can remain weakly power-relevant where outputs are easily substitutable, counterpart positions retain independent alternatives, or institutional rules prevent the advantaged capability from conditioning others' feasible actions.

18.2.4 Speed Asymmetry

Speed asymmetry concerns differences in the temporal profile of capability. Relevant dimensions include response latency, throughput, iteration frequency, monitoring continuity, adaptation rate, and synchronization across distributed operations. Speed matters economically because many opportunities and constraints are time-sensitive. A capability available after the relevant decision window can have a different practical status from the same capability available before commitment.

Artificial systems can compress cycles that previously required sequential human work. Drafting, coding, retrieval, translation, comparison, simulation, or monitoring can occur rapidly enough to change how often an organization revises its plan or how many alternatives it considers. Shorter cycles can transform the process itself by supporting more experiments, more frequent updates, or tighter coupling among decisions, thereby changing the structure of feasible coordination.

Temporal advantage is especially consequential in interactive environments. A

slower position can face a moving target if the faster position repeatedly observes, models, updates, and acts before the slower position completes one comparable cycle. Conversely, high speed can degrade capability when verification, reflection, or institutional process cannot keep pace. Rapid generation can create queues of outputs whose evaluation becomes the new bottleneck. Speed therefore interacts with attention, verification, and governance, and its value depends on those complementary capacities.

Definition 18.18 (Capability-latency asymmetry). A *capability-latency asymmetry* exists when comparable or functionally related operations become practically available to different positions on materially different temporal scales, and that timing difference changes which operations, responses, or coordination pathways remain feasible within the relevant horizon.

The definition emphasizes feasibility within the operative horizon, with clock speed serving as one component. Millisecond differences can be consequential in one domain and irrelevant in another; days can be decisive in a regulatory or scientific process while seconds are immaterial. Radical speed asymmetry therefore depends on the temporal structure of the field in which the capability is exercised.

Speed can also compound other asymmetries. Faster retrieval magnifies accessible knowledge; faster simulation amplifies computation; faster communication supports coordination; faster updating can improve adaptation. These interactions provide one route through which a moderate difference on several dimensions can form a more consequential joint asymmetry.

18.2.5 Memory Asymmetry

Memory asymmetry concerns differences in the capacity to retain, retrieve, connect, reconstruct, and operationalize past information across time. Storage volume is one component. Epistemically useful memory also requires indexing, provenance, contextual reconstruction, compatibility, permissions, and the ability to connect earlier records to current operations. Chapter 17's preservation analysis therefore applies directly: retained material can survive physically while becoming difficult to interpret or reuse.

Artificial systems can be connected to persistent stores that exceed unaided human recall in volume and retrieval speed. They can search logs, documents, code repositories, prior interactions, transaction histories, or model-generated records and make selected portions available during current work. Human memory has different strengths, including embodied continuity, meaning-laden recollection, context-sensitive association, and integration with personal or collective identity. Institutional memory can combine records with practices, roles, narratives, and tacit continuity. These forms should be compared by the functions they support, with storage capacity treated as one dimension.

Memory asymmetry becomes economically consequential when accumulated records lower the cost of future action. A system with access to detailed operational history can diagnose recurring faults, personalize interactions, reconstruct decisions, or identify patterns that another position cannot reproduce. An organization with preserved technical and institutional memory can adapt more quickly after disrup-

tion. A participant whose activity is comprehensively recorded can also become more legible to organizations that retain memory unavailable to the participant. The same memory infrastructure can therefore support capability, accountability, surveillance, or dependency according to its governance and access structure.

Definition 18.19 (Operational memory capacity). *Operational memory capacity* is the practically available capacity of a position to retain or access prior records and experience, reconstruct their relevant context and provenance, and incorporate them into present or future operations.

Definition 18.19 allows artificial, human, and institutional memory to be compared without requiring one common storage metric. The economically relevant question is what the retained past enables in later action.

Memory also contributes to cumulative advantage. A system that records the outcomes of repeated interactions can improve later prediction or adaptation; a human participant who loses access to that history can remain dependent on the system that retains it. This mechanism can generate persistence even if the underlying model remains unchanged.

18.2.6 Coordination Asymmetry

Coordination asymmetry concerns differences in the ability to combine heterogeneous capabilities into coherent collective action. Many economically consequential tasks depend on several agents, tools, infrastructures, institutions, and stages of work. The effective capability of a configuration therefore depends on interfaces, shared representations, protocols, sequencing, conflict resolution, and governance in addition to the component capabilities themselves.

Artificial systems can alter coordination in several ways. They can translate among formats, summarize distributed information, route tasks, monitor shared state, invoke tools, generate plans, or maintain communication across many concurrent operations. Software agents can sometimes be replicated or instantiated across tasks with lower coordination cost than assembling an equivalent number of human specialists. Human organizations, however, possess forms of coordination grounded in trust, authority, shared purpose, tacit convention, accountability, and social interpretation. The two profiles can differ in kind as well as scale.

A coordination advantage can magnify otherwise modest component capabilities. Several specialized systems connected through reliable interfaces can create a collective capacity unavailable to any component alone. The same applies to human teams and hybrid organizations. Conversely, highly capable components can produce weak collective performance when interfaces are incompatible, objectives conflict, provenance is lost, or errors propagate without review. Coordination asymmetry therefore concerns the organization of capability across relations.

Definition 18.20 (Coordination capability). *Coordination capability* is the practically available capacity of a relational configuration to allocate, sequence, synchronize, communicate, verify, and revise heterogeneous component operations so that they contribute to a declared collective task or generative process.

The definition makes collective capability irreducible to the sum of individual com-

ponents. A position can gain a radical coordination advantage through standards, APIs, shared memory, common models, institutional authority, or low-cost replication even when its component-level advantages are moderate.

Coordination also determines who can compensate for asymmetry. A single human participant can be weaker than an artificial system on several dimensions while a well-organized human institution retains strong collective capacity. Public infrastructure can pool verification and compute. Professional networks can distribute expertise. Open technical standards can make several providers interoperable. Capability comparison should therefore include the coordination structure through which counterpart positions can assemble alternatives.

18.2.7 Persistent Asymmetry

Radical capability asymmetry has a temporal structure. A large difference at one moment can disappear through diffusion, learning, investment, imitation, institutional adaptation, or technological substitution. A smaller difference can become more consequential when it is reproduced across repeated interactions and compounds into later capability. Persistence therefore requires attention to the mechanisms carrying capability differences across historical continuation.

Several mechanisms can renew artificial-capability asymmetry. Cumulative data can improve later models or operational systems. Revenue generated through existing capability can finance additional compute and engineering. Deep integration can create switching costs that preserve the position of one provider or technical architecture. Organizational learning can improve the ability to deploy the same model more effectively. Standards and interfaces can attract complementary investments. Persistent memory can lower future search and reconstruction costs. Skilled personnel can concentrate around institutions able to provide frontier tools and infrastructure. These mechanisms can reinforce one another without requiring a single centralized process.

Human capability can also adapt and accumulate. Repeated use of artificial systems can enlarge skill where participants learn to verify, direct, integrate, or extend the systems. Institutions can build public or shared infrastructure. Education can shift toward capabilities that remain complementary. New professions can emerge around evaluation, governance, domain integration, care, or embodied work. Persistent asymmetry is therefore a historical outcome whose reproduction mechanisms require explanation.

Definition 18.21 (Persistent capability asymmetry). *A persistent capability asymmetry is a directional capability difference whose supporting conditions are sufficiently renewed, accumulated, inherited, institutionally embedded, or costly to substitute that the difference remains economically consequential across the historical horizon relevant to the inquiry.*

Proposition 18.22 (Persistence-mechanism requirement). *A claim of persistent capability asymmetry should identify the mechanism that carries the difference across time, such as cumulative learning, data accumulation, infrastructure investment, switching cost, institutional embedding, standards, preserved memory, organizational complementarity, or recursive revenue and capability formation.*

Definition 18.21 and Proposition 18.22 align the chapter with the historical discipline used for power in Chapter 16. Persistence of capability remains distinct from persistence of power. A capability gap can endure while open access, regulation, substitution, or countervailing institutions prevent the advantaged position from conditioning others' feasible action. Section 18.3 will examine that additional step.

Persistent asymmetry can also change the baseline against which later differences are perceived. Once workflows, educational systems, markets, or institutions reorganize around artificial capability, operating without it can become increasingly costly even if the technical capability itself stops improving. Historical embedding can therefore deepen practical asymmetry through changes in complements and expectations as well as through improvements in the artificial system.

18.2.8 Limits of Capability Equalization

Capability asymmetry can be reduced through diffusion, access, education, shared infrastructure, institutional redesign, interoperability, public investment, or improved tools. Equalization nevertheless has several structural limits. First, access to the same artifact can produce different effective capability where complementary resources differ. Two organizations can use the same model while possessing different data, integration expertise, compute budgets, verification capacity, legal permissions, distribution channels, or organizational routines. Formal access can therefore coexist with substantial effective asymmetry.

Second, some capability differences arise through cumulative history. A participant receiving access today may not immediately reproduce years of organizational learning, preserved data, workflow redesign, trust relationships, or institutional reputation. Equalization of one input can narrow part of the gap while leaving historically accumulated complements unequal. These historically accumulated differences remain transformable, while diffusion should be evaluated across the configuration that produces effective capability, with artifact access treated as one component.

Third, multidimensional capability creates trade-offs. A policy that widens computational access can leave verification capacity concentrated. A system that equalizes retrieval can increase dependence on a common infrastructure. Standardization can improve interoperability while reducing diversity of technical approaches. Intensive AI assistance can raise current performance while weakening some forms of independent human practice if learning and skill maintenance receive little support. Equalization therefore concerns a profile of capabilities and dependencies across several dimensions.

Fourth, capability can be relationally positional. Some advantages depend partly on relative timing, exclusive access, scarce attention, strategic secrecy, or control of a bottleneck. If every participant receives the same faster tool, the absolute capability of the field can rise while the relative advantage associated with speed narrows. Other advantages can persist because the tool increases the returns to complementary assets held unevenly. The distributional effect therefore depends on the production structure into which capability diffuses.

Definition 18.23 (Capability-equalization profile). A *capability-equalization profile* records how an intervention changes the relevant dimensions of effective capabil-

ity, complementarity, substitution, dependence, and historical accumulation across the positions being compared.

Proposition 18.24 (Effective-capability conversion condition). *Equalization of access establishes comparable effective capability only where the complementary resources, verification, infrastructure, coordination, historical accumulation, and institutional permissions required for the relevant operations are also sufficiently comparable or substitutable.*

The proposition provides a direct bridge to the chapter's institutional analysis. Broad model availability can reduce one capability gap while leaving control over compute, infrastructure, standards, distribution, or decision authority concentrated. Conversely, public infrastructure and interoperable institutions can reduce effective asymmetry even when underlying technical systems remain unequal in frontier performance. The economically relevant object is the capability configuration created by the full arrangement.

The limits of equalization also clarify the meaning of *radical* in Definition 18.13. Radical asymmetry identifies configurations in which capability differences penetrate several mutually reinforcing dimensions or become embedded deeply enough that ordinary access to a tool does not readily restore comparable operational possibility. Such configurations can still be transformed through institutional, technological, educational, organizational, or infrastructural change. Their analysis requires identifying which dimensions are binding and which mechanisms reproduce them.

Section 18.3 now adds the stronger relational question. Capability asymmetry, even when radical and persistent, remains distinct from power. Power analysis asks whether capability differences are converted through dependency, infrastructure control, model control, access control, epistemic authority, decision mediation, or institutional arrangements into an effective capacity to deform or condition the feasible action and future possibilities of another position. The present section has supplied the multidimensional capability objects needed for that analysis while preserving comparison, persistence, and equalization as distinct problems.

18.3 Power under Capability Asymmetry

Section 18.2 established radical capability asymmetry as a multidimensional and historically embedded difference in practical capability. The present section asks the stronger relational question: under what conditions does such an asymmetry become power-relevant, and under what additional conditions does it support a claim about relational power? Its role is to connect the capability analysis of Chapter 18 to the revised power architecture of Chapter 16 without identifying technical superiority, productive abundance, or concentrated capability with power by definition. The discussion proceeds through dependency, control of infrastructure, control of models, control of access, epistemic authority, decision mediation, conversion of capability into power, and institutional mediation.

The distinction is analytically consequential. An artificial system can outperform a human participant on a specified task while remaining weakly connected to that participant's feasible action. A laboratory can possess frontier models while lacking

control over the infrastructure through which firms or public institutions operate. A platform can distribute a moderately capable system so widely that its interface choices condition millions of downstream decisions. A public institution can depend heavily on privately supplied artificial capability while retaining legal authority over the decisions in which that capability is used. These configurations cannot be ranked coherently by model performance alone. Power analysis requires identification of the relational mechanism through which capability changes accessible, feasible, or comparatively weighted future possibilities.

Chapter 16 supplied this discipline in three stages. Section 16.1 distinguished asymmetry from dependence, control, constraint, and power relevance. Section 16.2 then separated power relevance from relational power by requiring historical persistence together with causal and generative efficacy. Section 16.3 added manifestation, comparison, mediation, and reflexive recognition. The present section applies that architecture to artificial capability. Capability asymmetry supplies an antecedent relational difference. Dependency and control mechanisms can convert part of that difference into power relevance. Persistent and efficacious organization of those mechanisms can then support relational power. Manifestations such as rankings, model reputations, access tiers, benchmark claims, or institutional designations can subsequently affect how the power relation is recognized and reproduced.

The section therefore treats capability power as a relational achievement rather than a property stored inside a model. The relevant relata can include human participants, artificial systems, firms, public agencies, professional communities, infrastructures, or hybrid human–AI configurations. A capability advantage located in one component can become power-relevant for another component only through a specified relation. The same technical system can consequently support different power structures across organizations, jurisdictions, and historical periods.

Table 18.3 summarizes the principal conversion sites developed below.

18.3.1 Dependency

Dependency is the most direct route through which capability asymmetry can become relationally consequential. Chapter 16 treated dependence as reliance on resources, actions, knowledge, infrastructures, permissions, recognition, or complementary capacities located elsewhere. Artificial intelligence expands the possible objects of such reliance. A worker can depend on an AI-enabled workflow for access to current organizational tasks. A firm can depend on an external model provider for classification, translation, coding, forecasting, or customer interaction. A public institution can depend on privately maintained systems for analytical support. A research community can become reliant on computational infrastructure that is difficult to reproduce locally. A household can depend on AI-mediated interfaces for access to services whose underlying procedures remain opaque.

The existence of reliance remains insufficient for power. Modern production is constituted by reciprocal dependence, and specialization can enlarge collective capacity precisely because participants rely on complementary positions. The stronger issue is whether the dependency profile gives one position a durable ability to condition another's feasible action. Substitutability, switching time, interoperability, re-

Table 18.3: Mechanisms connecting capability asymmetry to power relevance

Mechanism	Power-relevant interface	Analytical safeguard
Dependency	A relevant capacity of one position relies materially on artificial capability, complementary infrastructure, or permission located elsewhere	Reliance becomes power-relevant only when alternatives, delay capacity, substitution, or exit are sufficiently constrained
Infrastructure control	One position governs compute, networks, data pipelines, identity systems, energy, deployment environments, or other required complements	Infrastructure ownership and infrastructure power remain distinct until control conditions another position's feasible operations
Model control	One position can modify, withhold, update, specialize, evaluate, or retire a model on which another position relies	Technical authorship or ownership does not by itself establish control over downstream possibility structures
Access control	Admission, pricing, rate limits, geographic availability, contractual terms, permissions, or interface rules condition practical use	Formal availability differs from effective access and from relational power
Epistemic authority	Artificial or institutionally mediated outputs receive standing in classification, verification, diagnosis, evaluation, or interpretation	Accuracy, expertise, authority, and power require separate identification
Decision mediation	Artificial systems structure options, rankings, defaults, recommendations, timing, or information available to decision processes	Influence over a decision differs from formal authority, while repeated mediation can still become generatively consequential
Capability conversion	A capability asymmetry systematically deforms another position's accessible, feasible, or weighted continuations	The conversion mechanism and generative dependence must be identified before a power attribution is made
Institutional mediation	Rules, offices, procurement, standards, liability, accreditation, or organizational routines stabilize capability-dependent relations	Institutional persistence can reproduce power while also enabling review, contestation, redistribution, or counter-capacity

tained human capability, legal rights, public alternatives, and the importance of the affected capacity all matter.

Definition 18.25 (Capability-conditioned dependency). A *capability-conditioned de-*

pendency exists when maintenance, exercise, or development of a capability materially important to one relational position relies on artificial capability, complementary infrastructure, access permission, or technical support controlled or supplied through another position, and when replacement or bypass is sufficiently costly, delayed, uncertain, or institutionally constrained over the horizon relevant to the inquiry.

Definition 18.25 treats dependence as a relation between capability configurations rather than as a psychological state. Participants can trust a system while remaining substitutable, or distrust it while lacking feasible alternatives. The economic significance lies in the organization of access and replacement.

Dependence can also be layered. A user may appear to depend on a model provider, while the provider depends on cloud compute, energy infrastructure, specialized chips, data suppliers, distribution platforms, or regulatory permissions. An organization can reduce dependence on one model by adopting several providers while remaining dependent on a common identity system, cloud environment, or technical standard. A public strategy focused only on visible model vendors can therefore miss deeper infrastructural dependencies.

Temporal exposure matters as well. A substitute that can be constructed in three years may offer little counter-capacity to an organization facing a service interruption tomorrow. Conversely, a concentrated provider can lose power relevance if affected positions possess credible migration pathways, preserved data portability, interoperable workflows, retained human expertise, and sufficient financial or institutional reserves to withstand transition.

Proposition 18.26 (Dependency power-relevance condition). *Capability-conditioned dependency becomes power-relevant when the dependent position's accessible or feasible operations change systematically with the supplying or controlling position's decisions, availability, conditions, or withdrawal, and the inquiry can identify the dependence mechanism connecting that position to the resulting change.*

The proposition carries the Chapter 16 distinction into the AI setting. Dependence supplies exposure. Power relevance requires directional consequence. Relational power requires the additional persistence and efficacy conditions developed later in Subsection 18.3.7.

18.3.2 Control of Infrastructure

Artificial productive capacity is supported by infrastructures that extend beyond the model itself. Compute clusters, chips, cloud services, energy, networks, data pipelines, storage, identity systems, deployment environments, software ecosystems, monitoring systems, payment rails, and physical facilities can each condition whether a capability is practically available. Control over these complements can therefore become a power-relevant interface even where several competing models exist.

The analysis should distinguish possession from control. An organization can own hardware while contractual or technical restrictions limit how it is used. A cloud provider can control scheduling and service conditions without owning the applica-

tions deployed by customers. A public institution can regulate infrastructure it does not own. Open-source software can reduce model-level control while leaving compute or deployment infrastructure concentrated. The relevant question is which position can change the conditions under which consequential operations remain feasible.

Definition 18.27 (AI infrastructure-control capacity). *AI infrastructure-control capacity* is the practically available capacity of a relational position to set, modify, enforce, suspend, prioritize, or condition the terms under which infrastructures required for artificial capability can be accessed or used in economically consequential operations.

Control can operate through price, allocation, technical architecture, contractual terms, service priority, geographic restriction, identity requirements, security policy, interoperability, or maintenance. Several forms can coexist. The definition does not imply that every infrastructural condition is discretionary. Physical scarcity, reliability constraints, safety requirements, or public-law obligations can shape the terms independently of any one controller.

Infrastructure power becomes especially important when capability can be reproduced at the model layer more easily than at the infrastructure layer. A model can be copied while high-end deployment, large-scale inference, secure integration, or low-latency service remains unavailable. Conversely, public or shared infrastructure can weaken private bottlenecks by making compute, storage, evaluation, or deployment environments more substitutable.

Control also has a generative dimension. Infrastructure choices can shape which organizational forms become viable, which research questions are affordable, which applications can scale, and which actors can accumulate later capability. A procurement standard can create a market for interoperable tools. A closed platform can encourage complementary investment around one architecture. A public compute facility can permit organizations lacking private capital to enter capability-intensive fields. These effects reach beyond immediate service availability because they alter later capability formation.

Proposition 18.28 (Infrastructure conversion condition). *Infrastructure control supports a power attribution only where the controlled infrastructure is sufficiently consequential to another position's feasible operations or capability development, and changes in the controlling position's terms or actions can be connected to changes in those possibilities through an identifiable mechanism.*

This condition prevents concentration statistics from substituting for power analysis. A concentrated infrastructure can be weakly power-relevant if switching is easy, public alternatives are robust, or users retain substantial counter-capacity. A less concentrated infrastructure can support strong local power where one provider is indispensable to a specific region, institution, or technical ecosystem.

18.3.3 Control of Models

Models occupy a distinct layer within the capability stack. A position can control model training, weights, deployment versions, system prompts, fine-tuning, safety

layers, tool connections, evaluation criteria, update schedules, retirement, and the interfaces through which the model becomes available. Each locus can alter downstream capability without changing the formal ownership of surrounding infrastructure.

Model control becomes economically salient because model behavior can change after organizations have reorganized workflows around it. An update can improve one capability while degrading another. A provider can retire an older version, change context limits, alter tool access, modify safety behavior, or change the cost structure. An organization using its own weights can retain greater version control while depending on external libraries, hardware, or data. Control should therefore be represented as a profile rather than as a binary attribute.

Definition 18.29 (Model-control profile). A *model-control profile* records which relational positions possess effective authority or technical capacity over the model functions relevant to an application, including training, modification, specialization, deployment, versioning, evaluation, updating, withholding, retirement, and connection to external tools or data.

The definition separates model control from model ownership. Openly licensed weights can reduce one form of control while operational deployment remains mediated by a platform. A proprietary model can be deeply customized inside an organization that retains control over local data, prompts, tools, and final decisions. A regulator can restrict a use case without controlling model design. Power analysis should identify which control dimension conditions the affected relation.

Model control can become generative because organizations adapt to model-specific affordances. Templates, data structures, staff training, verification routines, user expectations, and complementary software can accumulate around one system. Once such complements form, a model change can propagate through a larger relational configuration. The controller's influence then derives partly from historically generated dependence rather than solely from the model's current technical quality.

Model control also interacts with epistemic authority. A model that becomes widely used for classification or evaluation can affect the categories through which organizations understand cases, even when the provider lacks formal authority over final decisions. Section 18.3.5 develops this interface directly.

18.3.4 Control of Access

Access is the interface through which capability becomes practically available to downstream participants. Chapter 12 distinguished availability from effective access, and Chapters 17–18 repeatedly applied the same distinction to knowledge and artificial capability. Access control therefore deserves separate treatment from infrastructure and model control. A capability can exist, a model can be technically usable, and infrastructure can be physically present while contractual, financial, institutional, geographic, identity, or interface conditions keep the capability inaccessible to a particular position.

Access can be conditioned through pricing, usage quotas, rate limits, subscription tiers, account eligibility, geographic restrictions, procurement rules, organizational

permissions, safety filters, API scopes, data-residency requirements, or technical interoperability. These mechanisms can serve legitimate functions such as safety, reliability, privacy, compliance, or cost recovery. Their power relevance depends on how they condition another position's possibilities and on the availability of alternatives, review, and exit.

Definition 18.30 (Capability-access gate). A *capability-access gate* is a rule, interface, permission structure, price schedule, technical condition, or institutional procedure whose operation determines whether and under what terms a specified artificial capability can be practically mobilized by a relational position.

A gate can be public, private, automated, or distributed across several institutions. It can also be nested. A user may pass a platform gate while remaining unable to connect the model to organizational data. A firm may obtain API access while lacking regulatory permission for the intended use. A research institution may receive compute access while lacking the staff needed to use it effectively. The gate should therefore be tied to a declared capability rather than described generically.

Access power can also arise through priority rather than exclusion. Lower latency, higher quotas, early model access, preferential support, or privileged integration can change competitive timing and organizational learning. Capability asymmetry can therefore be reproduced through differentiated quality and timing of access even when all participants possess nominal entry.

Proposition 18.31 (Access-control power-relevance condition). A *capability-access gate becomes power-relevant when control of the gate systematically changes another position's practical capability, feasible operations, timing, or future capability formation, and the effect cannot be adequately explained without the gate's operation in the declared relational configuration.*

The proposition provides a bridge to later governance questions. Access regulation can reduce power by improving portability or public alternatives, and it can create power by centralizing approval in a new gatekeeper. The relevant analysis concerns the relational architecture produced by the intervention rather than an assumption that more or less access is uniformly preferable.

18.3.5 Epistemic Authority

Artificial capability can enter power relations through epistemic authority even when the system has no formal decision right. Chapter 17 distinguished epistemic asymmetry from power and treated authority, verification, interpretation, and institutional standing as separate dimensions of the epistemic economy. The present subsection asks how artificial outputs or AI-mediated institutions can acquire standing such that their classifications, predictions, summaries, diagnoses, evaluations, or recommendations condition the treatment of other positions.

Epistemic authority has at least three possible carriers. The artificial system itself can be treated operationally as an authoritative source by users. An institution can confer authority on outputs produced through a specified system. Human experts can acquire or lose authority through their ability to use, interpret, or contest artificial systems. These arrangements can coexist. A medical system, for example, may be

formally advisory while its outputs become practically difficult to challenge because organizations treat them as the default evidential baseline.

Definition 18.32 (AI-mediated epistemic authority). *AI-mediated epistemic authority* is a relationally conferred standing through which artificial outputs, AI-assisted judgments, or positions controlling their interpretation are treated as carrying consequential evidential, classificatory, predictive, or interpretive weight in a specified institutional or economic process.

The definition does not infer epistemic authority from accuracy alone. A highly accurate system can lack institutional standing. A system with modest accuracy can become consequential if procedures require participants to respond to it. Likewise, authority can be justified, contested, domain-limited, or provisional. The power question concerns whether that authority changes feasible action or standing for affected positions.

Epistemic authority can generate asymmetric burdens of contestation. A person may need to supply additional evidence to overturn an AI-assisted classification. A worker may have to explain deviations from an algorithmic recommendation. A researcher can face evaluation practices that reward compatibility with machine-readable metrics. A public official can rely on AI-mediated summaries whose omissions shape which alternatives receive attention. These effects do not establish injustice automatically, yet they can create power-relevant asymmetries by changing who bears the cost of explanation, verification, or appeal.

Authority can also become reflexive in the sense developed in Section 16.3. Widespread recognition of one system as authoritative can attract more users, data, integrations, and institutional reliance. Those changes can increase the system's practical capability and strengthen the authority initially attributed to it. The direction of the feedback remains contingent because visible failure, successful contestation, regulatory change, or competing systems can weaken the same loop.

18.3.6 Decision Mediation

Decision mediation concerns the organization of choice rather than formal decision authority alone. Artificial systems can determine which cases receive attention, how options are ranked, which predictions are displayed, what defaults are presented, how uncertainty is summarized, which actions are recommended, and how quickly a decision process moves. These functions can be consequential even when a human or institution retains the formal right to approve the final action.

The distinction between authority and mediation is important. A formal decision maker can remain legally responsible while practical dependence on an artificial system narrows the information and option set reaching that decision maker. Conversely, an artificial system can provide extensive analysis while human participants retain strong capacity to seek alternatives, inspect evidence, revise objectives, or ignore recommendations. Power relevance therefore depends on how mediation changes the decision possibility structure.

Definition 18.33 (AI decision-mediation profile). An *AI decision-mediation profile* records the ways in which artificial systems condition the information, option

set, ranking, timing, defaults, evidential presentation, uncertainty representation, or procedural sequence through which a specified decision is formed and implemented.

Decision mediation can operate at several stages. Upstream systems can determine which cases enter review. Midstream systems can score or classify cases. Downstream systems can generate recommended actions or automatically execute selected operations. The same organization can combine these stages. A useful analysis should therefore avoid describing the entire process as “AI decision making” when artificial systems mediate only some components.

Decision mediation becomes power-relevant when it systematically changes which continuations remain accessible to affected positions. A recommender can alter market visibility. A credit model can affect financing access. A hiring system can shape which applicants reach human review. A logistics optimizer can redirect work intensity and timing. A scientific assistant can reshape which hypotheses receive attention. In each case the model’s capability matters through an institutional or infrastructural pathway.

Proposition 18.34 (Decision-mediation conversion condition). *AI-mediated influence over a decision becomes power-relevant when the mediation mechanism predictably alters the decision process or the affected position’s feasible continuations, and the alteration remains consequential under the actual opportunities for review, override, alternative evidence, appeal, or exit.*

This condition also clarifies why nominal human oversight can vary substantially in meaning. Oversight is stronger where humans possess time, expertise, independent evidence, authority, and practical alternatives. It becomes thinner where the cost of deviation is high, model reasoning is difficult to inspect, workloads are excessive, or institutional routines reward compliance with the recommendation. The economic object is therefore the human–AI decision relation rather than the presence of a human signature at the final stage.

18.3.7 Conversion of Capability into Power

The preceding subsections identify several mechanisms through which capability asymmetry can acquire directional consequence. The present subsection integrates them using the power architecture developed in Chapter 16. The antecedent object is a typed capability asymmetry of the kind developed in Section 18.2. The conversion mechanism can involve dependency, infrastructure control, model control, access gating, epistemic authority, decision mediation, or a combination of these. The output of the first analytical step is power relevance rather than relational power.

Definition 18.35 (Capability-derived power relevance). A typed capability asymmetry is *power-relevant* in a specified human–AI or institutional configuration when an identifiable conversion mechanism connects the advantaged capability position to systematic deformation of another position’s accessible, feasible, or comparatively weighted operations, continuations, or capability-development pathways.

Definition 18.35 is a Chapter 18 specialization of the power-relevance architecture developed in Sections 16.1 and 16.2. The capability advantage does not need to be globally superior. A narrow advantage can become strongly power-relevant where

the affected relation depends heavily on that dimension. Large general capability differences can remain weakly power-relevant where institutions preserve substitution, exit, independent authority, or counter-capacity.

Power relevance can also be distributed. No single position may control the entire capability stack. One actor can control models, another cloud infrastructure, another identity or distribution, another institutional permission, and another the local workflow. Their combined arrangement can condition a participant's future possibilities even when each individual relation appears substitutable in isolation. The conversion analysis should therefore identify coupled mechanisms where the consequence emerges from several interdependent positions.

The transition to relational power requires stronger conditions. Section 16.2 requires the power organization itself to become historically persistent and causally and generatively efficacious. Applied here, a one-off model outage can create severe disruption without establishing a durable power structure. A temporary performance advantage can produce bargaining leverage without persisting long enough to reorganize the field. Conversely, recurrent dependence embedded in infrastructure, workflows, standards, and institutional expectations can support a relational power structure even where overt intervention is rare.

Proposition 18.36 (Capability-to-power conversion). *A capability-derived power-relevant relation supports a claim of relational power only when the resulting power organization satisfies the historical persistence, causal efficacy, and generative efficacy conditions required by Chapter 16. The capability asymmetry, the conversion mechanism, and the relationally realized power structure remain analytically distinct objects.*

The proposition yields several consequences. First, capability concentration is evidence about possible antecedent structure rather than proof of power. Second, power can persist after the original capability gap narrows if institutions, switching costs, standards, classifications, or expectations reproduce the relation. Third, a technically dominant system can lose power when counter-capacity, public infrastructure, interoperability, or institutional redesign weakens the conversion mechanism. Fourth, capability improvement by the less advantaged position does not automatically equalize power if access, authority, or dependency relations remain unchanged.

The distinction also clarifies reciprocal power. Human institutions can depend on artificial capability while model providers depend on market access, legal permission, high-quality data, professional expertise, public legitimacy, or infrastructure controlled by others. Reciprocal power can therefore coexist with radical capability asymmetry. Its analysis requires directional components rather than a single judgment about which entire position is more powerful.

18.3.8 Institutional Mediation

Capability-derived power rarely operates through technical relations alone. Procurement rules, employment contracts, professional standards, accreditation, liability, data-governance regimes, public law, organizational routines, technical standards, insurance, auditing, funding arrangements, and platform policies mediate how capability enters consequential activity. Institutions can amplify a capability advantage

by making one system or provider mandatory, and they can attenuate it by supporting portability, review, public alternatives, shared infrastructure, or countervailing expertise.

Institutional mediation also determines which capability counts. A benchmark can influence procurement. A certification can define which systems may enter a regulated domain. An organizational policy can require employees to use an approved assistant. A liability rule can make institutions prefer systems with auditable records over technically stronger but less governable alternatives. These arrangements alter the practical conversion from technical capability to economic power.

Definition 18.37 (Institutionally mediated capability power). *Institutionally mediated capability power* is relational power whose persistence or efficacy depends materially on rules, offices, standards, contractual arrangements, procedures, infrastructures, classifications, or organizational routines that connect capability asymmetry to consequential differences in access, standing, decision, coordination, or future capability formation.

The definition permits institutions to be constitutive supports without treating them as mere instruments of a technologically advantaged actor. Institutions have their own histories, mandates, conflicts, and sources of authority. A public agency can use private AI capability while imposing conditions that redirect its effects. A firm can constrain a model provider through procurement leverage. Professional communities can preserve human review standards. Workers can organize collective rules around monitoring or task allocation. Institutional mediation can therefore strengthen, distribute, constrain, or transform capability power.

Institutional mediation can also reproduce power indirectly. A classification produced through an AI-enabled process can determine eligibility; the resulting allocation can change later capability; the changed capability can then affect future classification or bargaining. This is a reflexive power-recognition loop of the kind developed in Section 16.3. The representation of capability can become part of the process that generates later capability and power.

A particularly important implication concerns governance. Interventions aimed at reducing technical asymmetry can be weak if institutional mediation continues to reproduce dependence. Conversely, governance can reduce power relevance without equalizing underlying capability by protecting exit, establishing appeal, requiring portability, providing public infrastructure, preserving independent expertise, or separating advisory systems from final authority. Section 18.13 will develop these governance questions at the chapter level.

Radical capability asymmetry supplies potential power relations, while relational conversion and historical realization determine whether capability becomes power. Dependency, infrastructure, model control, access, epistemic authority, decision mediation, and institutions are distinct conversion sites. Their interaction determines whether an artificial-capability advantage deforms another position's future possibilities. Persistent causal and generative efficacy can then sustain relational power in the sense developed in Chapter 16. Section 18.4 turns to labor, where capability and power encounter employment, distribution, care, contribution, and participation.

18.4 Labor after Artificial Intelligence

The preceding sections established three analytical layers: artificial productive capacity, radical capability asymmetry, and the mechanisms through which capability asymmetry can become power-relevant and eventually relationally powerful. The present section examines labor within that architecture. Its role is to analyze how artificial capability can reorganize tasks, relative productivity, employment opportunities, wage-based distribution, care, contribution, participation, and the form of work itself. The analysis treats displacement and complementarity as contingent outcomes whose historical form depends on task structure, organizational redesign, ownership, demand, bargaining, infrastructure, regulation, and the distribution of artificial capability.

The central analytical distinction is among *task performance*, *employment*, *income*, *contribution*, and *participation*. These objects can move differently. A task can become automatable while a job persists through reorganization. Human productivity can rise while labor's share of generated surplus falls. Employment can become scarcer while unpaid care, civic participation, cultural production, or relational work remain socially consequential. Wage income can decline in importance without resolving the institutional question of how access to material resources, recognition, learning, decision, and social membership should be organized. GRE therefore studies labor after artificial intelligence through the relations that connect productive capability to livelihood and participation.

Existing economic research supports task-level analysis alongside occupation-level analysis, especially where automation changes only selected operations within a wider role. Acemoglu and Restrepo distinguish the displacement of labor from the creation of new tasks that can reinstate labor demand (Acemoglu and Restrepo 2019). Recent generative-AI studies likewise show that artificial assistance can alter completion time and performance within bounded task settings, with heterogeneous effects across workers (Noy and Zhang 2023; Brynjolfsson et al. 2025). These results support a bounded conclusion: productive relations can be reorganized before the longer-run institutional form of the resulting labor market is known.

Table 18.4 summarizes the eight dimensions developed in this section.

18.4.1 Cognitive Automation

Cognitive automation concerns the transfer or reorganization of operations that previously required human cognitive performance within a labor process. Such operations can include drafting, retrieval, classification, translation, coding, summarization, scheduling, simulation, forecasting, comparison, monitoring, or recommendation. The economically relevant unit is therefore smaller than an occupation and often smaller than a conventionally defined task. A workflow can contain several operations with different requirements for context, responsibility, physical presence, judgment, verification, interaction, and authorization.

Artificial intelligence can affect these operations in several ways. It can replace direct execution by a human worker, reduce the time required for execution, change the skill threshold required for acceptable performance, externalize expertise into a

Table 18.4: Dimensions of labor transformation under artificial intelligence

Dimension	Economic question	Analytical safeguard
Cognitive automation	Which cognitive operations are transferred, compressed, or reorganized through artificial systems?	Task automation remains distinct from job elimination and from whole-process autonomy
Comparative human productivity	How does human productivity change relative to artificial or hybrid configurations?	Relative productivity is task-, organization-, and institution-specific and remains analytically separate from human worth
Employment scarcity	How many socially recognized paid roles remain available relative to people seeking them?	Employment scarcity differs from task scarcity, contribution scarcity, and material scarcity
Wage-based distribution	How strongly are access to income and social goods tied to employment income?	Productivity growth and income security need separate institutional analysis
Care and relational labor	Which activities derive value partly from situated relation, responsibility, presence, and continuity?	Technical substitutability in one task component leaves the value of the wider care relation to separate analysis
Human contribution beyond productivity	Which human contributions remain consequential outside output maximization?	Contribution includes judgment, responsibility, stewardship, legitimacy, meaning, and collective formation
Participation beyond employment	Through which institutions can persons participate in economic and social generation outside paid jobs?	Participation is broader than income receipt and broader than labor-market status
Transformation of work	How do task boundaries, skill, autonomy, monitoring, tempo, responsibility, and learning change together?	Work transformation is historical and path-dependent and requires more than an automation rate

shared system, generate candidate outputs that require later human verification, or create new coordination and supervision tasks. The task-based framework developed by Acemoglu and Restrepo is useful here because it distinguishes displacement effects from the creation of new tasks and the reinstatement of labor demand (Acemoglu and Restrepo 2019). GRE adds a relational question: how does each change reorganize the capability, dependency, learning, and bargaining structure of the participants who remain inside the production process?

Definition 18.38 (AI-mediated cognitive automation). *AI-mediated cognitive automation* occurs when one or more cognitive operations within a labor process are re-assigned, compressed, or reorganized through an artificial system such that completion of the process requires a changed form, timing, or quantity of direct human cognitive execution at those operations.

The definition is intentionally process-relative. A worker can remain employed after several operations are automated. An occupation can expand even as particular cognitive operations disappear. A new operation can arise because artificial output

requires verification, integration, exception handling, interface design, data preparation, or institutional authorization. Conversely, a technically feasible augmentation can still reduce employment if organizations redesign the process so that fewer workers are required for the same output.

The experimental evidence in professional writing and customer support illustrates this plurality. Generative-AI access improved performance in specified tasks in the settings studied by Noy and Zhang and by Brynjolfsson, Li, and Raymond, while the latter study also reports heterogeneous gains and patterns consistent with diffusion of organizational knowledge (Noy and Zhang 2023; Brynjolfsson et al. 2025). These settings show augmentation inside existing roles. The later organizational consequences remain open: redesign can preserve headcount, expand service volume, raise quality, change wages, or consolidate work among fewer employees.

Proposition 18.39 (Task–employment non-equivalence). *A reduction in the amount of direct human execution required for a specified cognitive operation leaves the employment effect of the wider labor process underdetermined. Employment consequences additionally depend on demand, process redesign, complementary tasks, organizational scale, costs, institutions, and the distribution of control over artificial capability.*

The proposition prevents task exposure from becoming a direct forecast of employment loss. The same automation can reduce labor demand in one organizational configuration and expand it in another if lower cost creates additional demand, if quality improvement opens new uses, or if complementary human tasks become more valuable. The economic analysis therefore has to follow the reconfiguration of the whole production relation.

18.4.2 Comparative Human Productivity

Artificial productive capacity changes the reference point against which human productivity is evaluated. A worker can become more productive in absolute terms after adopting an AI system while becoming less productive relative to an AI-intensive organizational configuration operated by fewer people. A human specialist can outperform a general-purpose model on a narrow domain while a hybrid team using artificial tools outperforms either component considered separately. Comparative productivity therefore depends on the unit of comparison.

Let a labor configuration retain a human participant h , an artificial system a , and organizational complements o . The relevant comparison can concern h acting independently, a operating through a specified deployment environment, or a hybrid configuration (h, a, o) . GRE treats these as different production configurations. Productivity comparisons across them require a declared output, quality criterion, time horizon, resource boundary, and consequence set. A comparison based only on tokens generated, cases completed, or immediate unit cost can omit verification, error correction, training, coordination, infrastructure, liability, or later capability loss.

Definition 18.40 (Comparative human productivity position). A person's *comparative human productivity position* is the task- and configuration-relative relation between the economically consequential outputs obtainable through that person's participation and the outputs obtainable through selected artificial, human, or hybrid comparison configurations under explicitly stated resource, quality, temporal, and

institutional conditions.

The definition separates comparative productivity from intrinsic personal quality. A person can occupy a weak comparative productivity position on one operation while contributing judgment, responsibility, relational continuity, legitimacy, or contextual knowledge that is not represented by the selected output metric. Conversely, a highly valued professional role can contain operations on which artificial systems achieve greater speed or consistency. Comparative productivity is therefore an economic relation among production configurations and remains separate from a general ranking of persons.

Capability diffusion can also change comparative positions unevenly. In the customer-support setting studied by Brynjolfsson, Li, and Raymond, less experienced workers received larger measured productivity gains than more experienced workers in the studied deployment (Brynjolfsson et al. 2025). One interpretation consistent with their evidence is that some tacit or organizationally accumulated knowledge became accessible through the assistant. If such diffusion generalizes in a domain, the productivity premium attached to prior experience can narrow for some operations while other forms of experience become more important for verification, escalation, or exceptional cases.

Proposition 18.41 (Productivity–contribution distinction). *A decline in a person’s comparative productivity position under a declared output metric leaves that person’s total economic or social contribution to separate analysis. The latter requires an account of the relations, responsibilities, meanings, institutional functions, and future generative effects omitted from the productivity metric.*

This distinction becomes increasingly important when artificial systems compress the market value of outputs that previously served as proxies for expertise. A draft, translation, image, or preliminary analysis can become inexpensive while responsibility for consequences, institutional trust, contextual interpretation, or long-horizon stewardship remains scarce. Labor institutions that equate contribution entirely with immediately measurable output can therefore misrecognize important forms of value under conditions of artificial abundance.

18.4.3 Employment Scarcity

Employment is one institutional form through which labor, income, status, time, training, social membership, and productive participation are bundled. Artificial intelligence can alter the scarcity of employment even where production becomes more abundant. The relevant scarcity concerns socially recognized paid roles available to people who seek them under prevailing institutional conditions.

Employment scarcity can arise through several mechanisms. Automation can reduce the number of workers required for a given output. Organizational consolidation can concentrate production in firms with strong model, compute, or distribution advantages. Productivity growth can outpace expansion of demand. New tasks can emerge more slowly than displaced tasks. Skills can become obsolete faster than institutions support transition. Geographic or legal constraints can prevent workers from entering newly created roles. Employment can also remain abundant in aggregate while becoming scarce for particular groups, regions, age cohorts, professions,

or capability profiles.

Definition 18.42 (Employment opportunity scarcity). *Employment opportunity scarcity* exists for a specified population and historical horizon when the set of practically accessible paid roles compatible with that population's location, capabilities, rights, transition resources, and institutional conditions is small relative to the population seeking such roles.

The definition is relational. A vacancy listed nationally can remain practically inaccessible to many workers. Access depends on skill conversion, migration, caregiving obligations, credentials, language, transport, digital infrastructure, health, discrimination, and the time and resources required for transition. Artificial intelligence can expand nominal opportunity while simultaneously increasing the distance between existing capability profiles and the roles through which income is distributed.

Korinek and Stiglitz analyze channels through which AI-related technological change can alter factor prices, distribution, and unemployment under specified conditions (Korinek and Stiglitz 2019). Their analysis underscores a broader point relevant here: technological productivity gains leave the distribution of resulting income institutionally open. Employment scarcity and material abundance can coexist when productive capacity expands faster than institutions reorganize distribution and participation.

Proposition 18.43 (Productive abundance–employment scarcity compatibility). *An economy can experience increasing productive abundance while simultaneously exhibiting employment opportunity scarcity for some populations. The two conditions concern different objects: productive abundance concerns the capacity to generate goods, services, or symbolic outputs, whereas employment scarcity concerns access to socially recognized paid roles.*

The proposition becomes central if artificial systems reduce the marginal human labor required for an expanding range of outputs. A society can then possess high aggregate production while using employment as the principal gate through which households gain income, insurance, housing access, creditworthiness, migration status, or social recognition. The resulting problem is jointly technological and institutional, with distribution depending on the rules through which claims on production are recognized. Section 18.4.4 examines the distributional side directly.

18.4.4 Wage-Based Distribution

Modern economic institutions commonly connect access to income with the sale of labor time, expertise, or responsibility through wages and salaries. This arrangement performs more than a pricing function. Wage income can provide access to consumption, savings, insurance, pensions, housing, credit, social status, and institutional standing. Artificial productive capacity therefore creates a distributional problem when production becomes less dependent on human labor while material access remains strongly tied to employment income.

The distributional effect depends on ownership and bargaining structures as much as on technology. Productivity gains can raise wages, profits, consumer surplus, tax revenue, or some combination. They can also support shorter work time, expanded

services, social investment, or retained earnings. Section 18.6 will examine ownership of productive intelligence and Section 18.7 will analyze AI-generated surplus. The present subsection isolates the labor-side linkage between livelihood and employment.

Definition 18.44 (Wage-dependence profile). *A wage-dependence profile specifies the extent to which a person's or household's effective access to material resources, insurance, social rights, institutional services, and future capability formation depends on continuing participation in paid employment.*

High wage dependence makes employment disruption economically consequential even when aggregate productive capacity is strong. A worker who loses a role can face immediate material scarcity while the economy that displaced the role produces more output than before. The relevant contradiction lies between the location of productive capacity and the institution through which claims on that production are recognized.

Wage-based distribution also affects bargaining. When workers require employment for basic material continuity and employers have access to increasingly substitutable artificial capability, the outside options of the two sides can change asymmetrically. Section 18.3 showed how capability differences can become power-relevant through dependence and access control. The same mechanism can enter labor relations when one side's ability to exit, retrain, relocate, or survive transition is much weaker.

Proposition 18.45 (Wage-distribution decoupling condition). *Where artificial productive capacity reduces the human labor required for economically significant output while effective access to resources remains strongly wage-dependent, the institutional linkage between contribution to production and claims on production can weaken. The distributional consequences depend on ownership, bargaining, taxation, transfers, public provision, and other allocation institutions.*

This proposition leaves the continued role of wage labor open. It identifies a pressure on wage-centered distribution when human labor becomes a less necessary input for some forms of production. A policy response based only on preserving employment can then conflict with the productivity gains that make less labor technically possible. Conversely, an income-only response can leave recognition, participation, learning, contribution, and institutional standing unresolved. Section 18.8 will examine redistribution and these wider limits.

18.4.5 Care and Relational Labor

Care exposes the limits of reducing labor to output quantity. Care work can include feeding, cleaning, nursing, teaching, listening, accompanying, coordinating, protecting, interpreting needs, maintaining households, sustaining relationships, and supporting dependency across the life course. Feminist economics has long shown that such activity crosses paid and unpaid domains and is often undervalued or excluded from conventional economic measurement (Folbre 2001; England 2005; Power 2004). Artificial intelligence changes parts of this activity while leaving open the status of the wider relation.

Some care operations are amenable to substantial technical support. Scheduling, documentation, monitoring, translation, reminders, information retrieval, administrative triage, and routine communication can be partly automated. Robotics and sensing can further change embodied support. These changes can reduce burdens and free human time for direct relational interaction. They can also intensify surveillance, standardize care pathways, reduce staffing, or shift responsibility toward recipients and families. The same technical capability can therefore support different care regimes depending on how institutions reorganize labor around it.

Definition 18.46 (Relationally situated care labor). *Relationally situated care labor* is work whose economic and social significance depends materially on an ongoing relation of attention, responsibility, responsiveness, trust, presence, or continuity with a person or group whose needs cannot be represented adequately by output quantity alone.

The definition leaves the possible participants in care open and specifies the relational conditions relevant to substitution or complementarity. It identifies the relational conditions that any proposed substitute or complement would have to address. An artificial system can perform a technically competent care-related operation while the surrounding care relation continues to depend on human responsibility, legal accountability, embodied presence, mutual recognition, or long-horizon knowledge of the cared-for person. Future institutions may also develop new forms of human–AI care relation whose value requires separate analysis.

Care therefore provides a strong case for distinguishing automation of components from substitution of the whole relation. A system that drafts clinical notes can reduce documentation time while leaving diagnosis, consent, responsibility, emotional support, and bodily care with human participants. A conversational system can provide companionship-like interaction while questions of dependency, authenticity, privacy, continuity, and social withdrawal remain open. The appropriate economic comparison should include these relational consequences.

Proposition 18.47 (Care-task substitution boundary). *Technical substitutability of one or more operations within a care process establishes substitution only for those operations. Substitution of the wider care relation requires a separate account of responsibility, responsiveness, trust, continuity, embodiment, recognition, and the needs of the affected participants.*

This distinction has distributional implications. If AI lowers the cost of some care operations, institutions can use the gain to reduce burdens, expand access, shorten working hours, or increase relational time. They can also use the same gain to cut staffing and compress interaction. The technological change therefore opens a generative choice among several possible care regimes.

18.4.6 Human Contribution beyond Productivity

Artificial intelligence makes the category of contribution more visible because productive performance can become increasingly detached from human effort. When a machine-assisted configuration produces a high-quality output rapidly, the economic question shifts from how much labor was required toward which forms of human participation remain consequential and how institutions recognize them.

Human contribution can include responsibility for consequences, specification of purposes, judgment under ambiguity, care, interpretation, stewardship, conflict mediation, representation of affected communities, legitimacy, historical memory, cultural continuity, aesthetic orientation, ethical reflection, and maintenance of institutions through which collective life remains possible. Some of these contributions can also be supported by artificial systems. Their importance lies in the relations they organize, while the distribution of relevant capabilities across humans and artificial systems remains an open empirical and conceptual question.

Definition 18.48 (Non-productivity-reducible contribution). A *non-productivity-reducible contribution* is a contribution whose economic or social significance cannot be represented adequately by the quantity, speed, or unit cost of output because its value depends materially on responsibility, relation, legitimacy, continuity, judgment, meaning, stewardship, or another context-sensitive generative effect.

This category is compatible with rigorous evaluation. Rigorous scrutiny remains available because the evaluative object differs from immediate output productivity. A public decision can require legitimate representation even if an automated system predicts outcomes more accurately. A scientific institution can value mentorship because it forms future researchers. A community can value cultural transmission because it sustains identity and shared meaning. A care institution can value continuity because repeated relationships affect trust and responsiveness.

The distinction also interacts with comparative human productivity. If artificial systems outperform humans on increasingly many measurable outputs, institutions that use output metrics as the exclusive basis of contribution can generate systematic devaluation of human roles whose consequences remain socially necessary. Conversely, invoking meaning or dignity cannot by itself justify preserving every existing occupation. GRE therefore asks which relational and generative functions remain consequential and whether they can be organized through forms other than conventional employment.

Proposition 18.49 (Contribution-recognition condition). *Where socially consequential human contributions are weakly represented by prevailing productivity metrics, labor-market valuation alone can provide an incomplete account of their generative significance. Institutional recognition requires criteria matched to the relational and temporal effects actually under evaluation.*

The proposition prepares the next subsection. Once contribution is separated from paid employment, the economic architecture can examine participation through a wider set of institutions.

18.4.7 Participation beyond Employment

Employment currently performs several participatory functions simultaneously. It can provide income, routine, social contact, recognition, collective identity, learning, responsibility, status, and a pathway into institutions. If employment becomes scarcer or less central to production, replacing only the income function leaves these other roles unresolved. The problem is therefore broader than redistribution.

A capability-oriented perspective helps clarify the issue. Sen's account of substan-

tive freedom emphasizes what people are effectively able to do and to be, together with the institutions that expand or constrain those possibilities (Sen 1999). GRE extends this concern to generative participation: whether persons can enter relations through which they contribute, learn, care, create, deliberate, organize, preserve, and influence future collective conditions.

Definition 18.50 (Economic participation beyond employment). *Economic participation beyond employment* consists of institutionally recognized opportunities to contribute to, influence, learn within, care for, maintain, create, or govern economically consequential relational processes without requiring that participation to take the form of a conventional wage-employment contract.

Possible institutional forms include cooperatives, commons, public service, civic institutions, research communities, artistic and cultural production, care networks, mutual aid, community governance, education, open-source production, deliberative bodies, and new arrangements whose stable form has yet to emerge. The definition leaves compensation arrangements open; time security, access rights, recognition, and protection against exploitation remain central questions.

Participation beyond employment also raises the issue of access to productive intelligence. If meaningful participation increasingly requires AI capability, compute, data, or institutional interfaces controlled by a small number of organizations, non-employment participation can reproduce dependency structures of the kind analyzed in Section 18.3. Public, cooperative, or commons-based access can therefore become part of the infrastructure of participation itself.

Proposition 18.51 (Participation–income non-equivalence). *Material income security and meaningful economic participation address different dimensions of post-employment order. Income can expand effective choice while leaving contribution, recognition, learning, institutional voice, relational continuity, or access to generative infrastructures weakly developed.*

The proposition adds a second institutional layer alongside income security. A society with high material security can still concentrate consequential decision and creation inside a narrow set of organizations. Conversely, extensive participation without material security can become coercive or exploitative. Long-horizon labor institutions therefore have to coordinate livelihood and participation rather than assuming one automatically supplies the other.

18.4.8 Transformation of Work

Artificial intelligence can transform work even where employment levels change little. Tasks can be redistributed between humans and artificial systems; skill requirements can shift; monitoring can become more granular; decision rights can move; the tempo of work can accelerate; output expectations can rise; learning can be compressed or displaced; responsibility can remain human while execution becomes machine-mediated; and workers can become dependent on systems they do not control. The object of analysis is therefore the changing relational organization of work.

Algorithmic management already demonstrates that computational systems can direct, evaluate, and discipline work through repeated organizational mechanisms

(Kellogg et al. 2020). Generative systems add a second layer because they can participate directly in the production of text, code, analysis, images, decisions, and communication. This combination can alter both what workers do and how their activity is observed, compared, and governed.

Definition 18.52 (AI-mediated work-transformation profile). *An AI-mediated work-transformation profile is a structured description of changes in task composition, capability requirements, autonomy, monitoring, decision rights, responsibility, learning opportunities, tempo, coordination, bargaining position, and dependence that arise when artificial systems are incorporated into a labor process.*

The profile is multidimensional because desirable changes in one dimension can coexist with adverse changes in another. Automation can remove repetitive work while increasing monitoring. Decision support can improve accuracy while narrowing professional discretion. AI assistance can accelerate novice learning in one setting while sustained reliance weakens independent capability in another. Productivity gains can shorten work time or raise expected output per worker. The outcome depends on institutional design and bargaining as well as technical capability.

Work transformation is also path-dependent. Organizations build data pipelines, interfaces, training practices, performance metrics, job descriptions, and management routines around particular systems. Workers adapt their skills to the resulting workflow. Once these complementary investments accumulate, switching technologies or restoring previously displaced human capabilities can become costly. A temporary assistance arrangement can thereby become a durable dependency relation even if alternative systems later become technically available.

Proposition 18.53 (Path-dependent work transformation). *Repeated incorporation of artificial systems into labor processes can alter future work through accumulated changes in skills, routines, infrastructure, evaluation, and organizational expectations. The long-run labor effect therefore depends on the historical path of incorporation as well as on the contemporaneous capability of the artificial system.*

This proposition reconnects labor to the generative-relational framework of the book. Work is a site where present allocation changes future capability. A workplace that uses artificial systems to expand human learning, reduce burdens, preserve autonomy, and distribute gains generates a different future from one that uses the same technical capability to deskill workers, centralize decision, intensify monitoring, and externalize transition costs. The technology can be similar while the relational history diverges.

Labor after artificial intelligence therefore concerns more than employment volume. Automation reshapes task composition; productivity shifts relative positions; employment and wages organize livelihood; care and other contributions reveal value beyond output; participation and work design shape future capabilities. Section 18.5 examines subjecthood and existential participation once productive necessity and social membership become less tightly bundled through wage employment.

18.5 Subjecthood and Existential Participation

Section 18.4 distinguished task performance, employment, income, contribution, and participation under conditions of expanding artificial productive capacity. The present section develops the corresponding problem of subjecthood. Its role is to analyze the economic relations through which persons acquire and maintain social position, recognition, reciprocal significance, meaningful participation, learning, care, curiosity, aesthetic orientation, and continuity of life projects when paid employment becomes a less reliable organizing center. The objective is neither to derive a complete philosophy of human meaning nor to treat employment as the historical source of every valued relation. The section identifies a bounded economic architecture in which institutions, resources, technologies, and relational arrangements can support or weaken forms of participation that matter to subjects across time. The discussion proceeds through work and social position, contribution, being needed, meaningful participation, learning relations, care relations, curiosity and knowing, aesthetic orientation, and subjective continuity beyond employment. The method is relational, capability-oriented, and historically cautious: existential participation is studied through observable or reconstructable conditions of access, recognition, reciprocity, responsibility, continuity, and future possibility while stronger claims about subjective experience remain outside the economic formalism.

GRE has already treated economic subjecthood as heterogeneous and historically constituted rather than as a fixed property of one canonical actor type. Chapter 12 distinguishes persons, households, organizations, communities, institutions, artificial systems, and non-human participants while preserving differences in agency, experience, responsibility, recognition, and normative standing. Chapter 17 further develops knowing as relational participation and shows how learning can alter a subject's later epistemic capability, orientation, and subjective continuity. The present section uses those foundations to ask a different question. When artificial systems reduce the amount of human labor required for production, which economic arrangements continue to connect persons with roles through which they can participate in social generation and maintain historically extended projects?

Several established traditions illuminate parts of this question without supplying one unified answer. Sen's capability approach emphasizes substantive opportunities to do and be rather than resource possession alone (Sen 1999; Sen 1992). Honneth's work on recognition distinguishes social recognition from mere perceptual visibility and analyzes recognition as important to social relations and self-relation (Honneth 2001; Honneth 1995). Arendt distinguishes labor, work, and action in a historically influential account of active life, while the present chapter uses those distinctions only as a reminder that paid employment does not exhaust the forms through which persons can appear, make, act, and participate in a common world (Arendt 1958). Wenger's account of communities of practice similarly connects learning with practice, meaning, community, and identity (Wenger 1998). GRE places these heterogeneous insights inside an economic inquiry into the infrastructures and institutional conditions that distribute participation opportunities.

Definition 18.54 (Existential participation in the economic domain). *Existential participation in the economic domain* is a historically extended relation through

which a subject can take part in consequential practices, contribute to shared or personal projects, receive or contest recognition, sustain reciprocal relations, and connect present activity with future possibilities in ways that matter to the subject's continuing position in economic and social life.

Definition 18.54 is deliberately narrower than a general theory of meaning. It identifies economic conditions under which participation can become consequential for subject formation and continuity. A person can have material income while lacking access to such relations; another can participate meaningfully through unpaid care, study, art, civic practice, scientific inquiry, community stewardship, or collective organization. The definition therefore prevents income security from standing in for the entire participatory problem while preserving the importance of material conditions for sustained participation.

Table 18.5 summarizes the nine dimensions developed in this section.

18.5.1 Work and Social Position

Paid work commonly bundles several economic and social functions that can be separated analytically. Employment can provide income, daily temporal structure, occupational identity, recognized competence, access to colleagues, institutional standing, opportunities for learning, bargaining position, benefits, and a visible route through which contribution is socially registered. These functions vary across occupations and societies. Precarious, coercive, stigmatized, unsafe, or poorly compensated work can provide some functions while damaging others. The present analysis therefore treats the employment bundle as historically contingent rather than intrinsically beneficial.

Artificial intelligence can unbundle these functions by changing the demand for human task execution before alternative institutions have developed to carry the remaining roles. A person can retain income through transfers while losing occupational networks and routine. Another can leave paid employment while gaining time for care, study, artistic work, community activity, or entrepreneurship. A third can remain employed while losing discretion, learning opportunity, or recognized authorship because AI-mediated workflows centralize control elsewhere. The relevant transition is therefore multidimensional.

Definition 18.55 (Employment-linked social-position bundle). An *employment-linked social-position bundle* is the set of income, temporal, relational, recognitional, institutional, developmental, and participatory functions that a historically specified employment relation provides to a subject.

The bundle in Definition 18.55 can be decomposed rather than treated as one good. This decomposition matters for AI-era policy because replacing lost wages addresses one component. Social networks, recognized roles, learning trajectories, professional standing, and the ability to participate in consequential collective projects can require different institutional arrangements.

Capability analysis is useful here because access to a nominal institution does not guarantee substantive opportunity to use it (Sen 1999). A publicly available learning platform, civic forum, makerspace, or community organization can provide formal

Table 18.5: Dimensions of subjecthood and existential participation under artificial intelligence

Dimension	Participatory relation	Economic question
Work and social position	Employment and occupational roles connect income, routine, recognition, institutional standing, and social networks	Which functions remain attached to work, and which require alternative institutions when employment becomes less central?
Contribution	Activity enters a shared project, relation, institution, or future possibility	How are consequential contributions identified, supported, attributed, and sustained outside narrow productivity metrics?
Being needed	Other persons or institutions possess reason-sensitive dependence on a subject's participation	Which forms of reciprocal significance can remain meaningful without creating avoidable coercive dependency?
Meaningful participation	Subjects have consequential roles with intelligible stakes, agency, feedback, and continuity	Which institutional arrangements make participation substantive rather than nominal?
Learning relations	Participation changes later capability, orientation, and entry into practices	How can learning remain a mode of participation rather than merely preparation for scarce employment?
Care relations	Responsibility and responsiveness are organized across vulnerable or dependent relations	How are care, recognition, continuity, and burden distributed when technical systems mediate care?
Curiosity and knowing	Subjects can encounter, inquire, interpret, and sustain open-horizon learning	How are time, access, security, and epistemic infrastructure distributed for inquiry beyond immediate market demand?
Aesthetic orientation	Subjects participate in practices of perception, judgment, making, and cultural interpretation	How are capacities for aesthetic orientation cultivated and protected under symbolic abundance?
Subjective continuity	Present participation remains connected with remembered commitments, skills, relations, and future projects	Which economic conditions support continuity while allowing revision, transition, and plurality of life paths?

access while remaining practically inaccessible because of time scarcity, disability, language, care responsibilities, cost, geography, confidence, or exclusionary norms. Post-employment participation therefore requires attention to conversion conditions as well as provision.

Proposition 18.56 (Employment-bundle decomposition). *A decline in paid employment can alter income, recognition, routine, learning, social connection, institutional standing, and participation through different mechanisms. Institutional responses that replace one component leave the remaining components analytically open.*

Proposition 18.56 avoids treating either employment preservation or income replacement as a complete response to AI-mediated labor transformation. The relevant design problem concerns which valuable functions should remain linked to employment and which can be supported through other institutions.

18.5.2 Contribution

Contribution concerns how a subject's activity enters the generation, maintenance, interpretation, repair, or transformation of a relation, project, institution, community, body of knowledge, environment, or future possibility. Section 18.4.6 already separated human contribution from productivity. The present subsection develops the subject-side relation: how contribution becomes a route through which a person participates in a shared world and sees a connection between action and consequence.

Contribution can be productive in the conventional sense, yet the category is wider. Maintaining an archive, caring for a dependent person, mentoring a novice, repairing a shared tool, preserving a language, moderating a community, producing art, serving on a local committee, generating a research question, or providing testimony can be consequential even where market output is difficult to measure. The same activity can also be burdensome, coerced, invisible, or exploited. Contribution therefore carries descriptive and normative questions that should remain separate.

Definition 18.57 (Relational contribution). A *relational contribution* is an action or sustained practice through which a subject makes a traceable difference to the maintenance, transformation, interpretation, accessibility, or future generativity of a declared relational configuration.

Definition 18.57 requires a declared configuration because contribution is purpose-relative. An action can contribute to an organization while damaging a community, or sustain a household while constraining the caregiver's own future possibilities. Evaluation therefore requires attention to the configuration, beneficiaries, burdens, alternatives, and historical consequences.

Attribution also matters. AI-mediated production can make causal contribution difficult to recognize when model outputs, organizational routines, human review, data infrastructures, and prior knowledge are combined. A contributor can remain economically consequential while becoming symbolically invisible. Conversely, visible credit can overstate a subject's actual contribution. The epistemic economy developed in Chapter 17 therefore intersects directly with contribution: provenance, attribution, classification, and recognition condition how contribution is socially represented.

Proposition 18.58 (Contribution-recognition non-equivalence). *Relational contribution and recognized contribution can diverge. AI-mediated production can increase this divergence when output is generated through distributed human, institutional, infrastructural, and artificial inputs whose provenance is only partially represented.*

The proposition makes recognition a separate institutional problem. A society can support broad participation only weakly if consequential contribution routinely disappears from its systems of credit, standing, or decision.

18.5.3 Being Needed

The experience or social fact of being needed deserves careful treatment because it can support reciprocal significance while also becoming a source of coercion. Employment often creates one form of need: an organization depends on a worker's labor, and the worker depends on employment income. Care creates another form: a child, patient, family member, colleague, or community can depend on a person's attention, judgment, continuity, or presence. Collective projects create further forms when participants possess specialized knowledge, trust, responsibility, or history that cannot be substituted immediately.

GRE can analyze neededness without making dependency itself a normative ideal. Some forms of dependency should be reduced because they expose a subject to domination, exhaustion, or irreplaceable burden. Other forms express reciprocal commitment or differentiated responsibility. The analytical object is therefore the structure and quality of dependence.

Definition 18.59 (Reason-sensitive neededness relation). *A reason-sensitive neededness relation exists when another subject, group, institution, or continuing project has identifiable reasons for the participation of a particular subject or for a capability carried by that subject, and substitution would alter relevant relational, practical, historical, or normative properties of the configuration.*

The reference to identifiable reasons in Definition 18.59 prevents neededness from being inferred solely from a person's desire to feel indispensable. The relation can be grounded in competence, trust, responsibility, historical continuity, embodied presence, legal role, care commitment, authorship, or other specified features. Some of these features are substitutable over time; others are partly constituted by the history of the relation.

Artificial systems can reduce certain forms of operational dependence by making expertise, communication, drafting, monitoring, or coordination easier to substitute. They can also create new neededness relations around verification, stewardship, responsibility, governance, or interpersonal continuity. The economic question is therefore not whether human beings remain indispensable in an abstract sense. It is how different forms of reciprocal dependence are generated, distributed, supported, and made revisable.

Proposition 18.60 (Neededness-dependency distinction). *An economically meaningful neededness relation can coexist with substitutability, shared responsibility, and institutional redundancy. The participatory significance of being needed therefore does not require making another position unable to continue without one specific person.*

This distinction is important for institutional design. Systems can create meaningful responsibility while maintaining backup, respite, transferability, and contestability. Such arrangements can preserve reciprocal significance without converting it into avoidable vulnerability or monopoly over a social role.

18.5.4 Meaningful Participation

Participation can be nominal or consequential. A person may be formally included in an institution while possessing little influence, little intelligibility about what the

activity serves, weak feedback about consequences, or no durable route to develop capability. Meaningful participation therefore requires more than presence. It concerns the relation among agency, intelligibility, consequence, recognition, and continuity.

This formulation remains compatible with plural conceptions of meaning. GRE does not define one substantive life plan as economically superior. A research community, family, religious association, artistic practice, cooperative, civic body, enterprise, neighborhood organization, educational institution, or individual long-horizon project can each organize participation differently. The economic role of GRE is to identify the material and institutional conditions that enable subjects to enter, sustain, revise, and leave such relations.

Definition 18.61 (Meaningful economic participation). *Meaningful economic participation* is participation in a consequential practice or project for which the subject has sufficient practical access, intelligibility, agency, feedback, recognition, and temporal continuity to form and revise a relation to what the participation generates.

The elements in Definition 18.61 need not be equal or maximal. Apprentices can participate before possessing full competence; patients can participate in care decisions with asymmetric expertise; citizens can participate through representation; children can participate under age-appropriate forms of support. The definition identifies dimensions that can be examined rather than a universal threshold.

Recognition is especially relevant because social visibility and social recognition can diverge. Honneth's analysis of invisibility shows how a person can be perceptually present while socially unrecognized (Honneth 2001). AI-mediated institutions can reproduce this divergence when automated systems process a person's data, labor, or preferences while the person has little standing as a participant in the decisions or practices that use them.

Proposition 18.62 (Participation-substance condition). *Formal inclusion provides a participatory opportunity whose substantive significance depends on practical access, intelligibility, agency, feedback, recognition, and continuity in the relevant configuration.*

The proposition connects participation to the capability approach without equating capability with subjective meaning. It states an institutional condition: opportunities become more substantive when subjects can actually convert them into consequential participation.

18.5.5 Learning Relations

Learning can function as a mode of participation as well as preparation for employment. Chapter 17 defined relational epistemic participation as temporally extended involvement through which capacities, orientations, relations, or feasible inquiries can change. Under conditions of employment scarcity, this role becomes economically more important because education can no longer be interpreted only as investment in later labor-market productivity.

A learning relation can connect a subject to teachers, peers, texts, instruments, practices, traditions, institutions, environments, and artificial systems. Lave and

Wenger's account of legitimate peripheral participation emphasizes changing participation within social practice, while Wenger later links learning with practice, meaning, community, and identity (Lave and Wenger 1991; Wenger 1998). These accounts support an economic question about access: who has time, security, infrastructure, mentors, communities, and legitimate entry into practices through which learning becomes a continuing part of life?

Definition 18.63 (Participatory learning relation). A *participatory learning relation* is a learning configuration in which changes in capability occur through sustained participation in a practice, community, object relation, or human–AI interaction whose significance extends beyond a one-time acquisition of information.

Artificial intelligence can widen access to explanation, translation, feedback, simulation, and individualized practice. It can also externalize operations that previously contributed to learning, leaving assisted performance high while independent capability changes little. Section 17.14 developed this distinction directly. The present subsection adds a participatory implication: learning institutions should be evaluated partly by whether they preserve opportunities for subjects to become more capable participants rather than only more efficient consumers of generated answers.

Proposition 18.64 (Learning-participation condition). *Where employment becomes a weaker organizer of adult life, access to continuing learning can function as a primary participation infrastructure when it provides sustained entry into practices, communities, inquiry, and capability development rather than only episodic credential acquisition.*

This proposition does not make perpetual schooling a social objective. It identifies learning as one candidate institutional route through which subjects can remain generatively connected to changing practices across a long life course.

18.5.6 Care Relations

Care relations combine practical activity with responsibility, responsiveness, dependency, continuity, and recognition. Section 18.4.5 showed that technical substitution of a care-related operation does not establish substitution of the whole care relation. The present subsection examines the subjecthood implication. Giving and receiving care are ways through which subjects become situated in relations of need, responsibility, trust, vulnerability, and mutual transformation.

Care scholarship has long emphasized that care work contains relational and affective dimensions alongside measurable service output (Folbre 1994; Folbre 2001; England 2005). GRE retains that insight while avoiding romanticization. Care can generate attachment and meaning, yet it can also impose unequal burdens, constrain future possibilities, and become exploitative when responsibility is concentrated without adequate resources, respite, recognition, or choice.

Definition 18.65 (Existentially consequential care relation). An *existentially consequential care relation* is a care configuration in which responsibility, responsiveness, continuity, recognition, or embodied presence materially affects the subject positions and future possibilities of one or more participants in addition to the completion of care-related tasks.

AI can mediate such relations through monitoring, scheduling, translation, reminders, decision support, companionship interfaces, or robotic assistance. These tools can reduce burden or expand access. They can also change who is responsible, who remains attentive, how needs become legible, and whether human participants retain the capacity to notice conditions outside the system's categories. The relevant question is therefore relational reorganization rather than a binary choice between human and artificial care.

Proposition 18.66 (Care-mediation condition). *AI-mediated improvement in a care operation can enlarge the quality or accessibility of a care relation when the surrounding configuration preserves adequate responsibility, responsiveness, contestability, and continuity; the same operational improvement can weaken the relation when those supports are displaced or obscured.*

The proposition keeps technical performance and relational quality analytically distinct while permitting complementarity between them.

18.5.7 Curiosity and Knowing

Curiosity and knowing provide another participation route whose economic significance can increase when paid employment occupies less of a person's time or social identity. Chapter 17 treated curiosity and question formation as processes whose emergence depends on encounter, salience, time, education, security, institutions, and relational support. It also treated knowledge beyond immediate instrumental utility as part of the epistemic economy. The AI-era question concerns whether productive abundance is accompanied by broader access to open-horizon inquiry or by deeper concentration of attention and epistemic orientation.

The economic resources required for curiosity are unevenly distributed. Time, quiet, libraries, networks, language access, mentors, communities, instruments, travel, computational resources, and freedom from immediate insecurity affect which subjects can sustain inquiry. AI can reduce some entry costs through explanation, search, translation, simulation, and conversational interaction. It can also channel curiosity toward highly represented materials, make generated answers cheaper than sustained inquiry, or increase dependence on platforms that shape what is encountered.

Definition 18.67 (Open-horizon participatory inquiry). *Open-horizon participatory inquiry* is sustained participation in questioning, learning, interpretation, or investigation whose relevant future significance is only partially specified at the time of participation and whose continuation can modify the subject's capabilities, orientations, relations, or later projects.

The definition preserves the possibility that inquiry later becomes economically instrumental while leaving room for historical, philosophical, scientific, cultural, personal, or civic inquiry whose immediate market return is weak. Dewey's account of inquiry is useful here because it places perplexity, observation, suggestion, and inference inside an educative process rather than treating inquiry as passive information receipt (Dewey 1910).

Proposition 18.68 (Curiosity-opportunity condition). *Productive abundance enlarges*

existential participation through curiosity only where subjects gain practical access to the time, security, epistemic resources, communities, and contestable infrastructures required to sustain inquiry and form their own questions.

The proposition gives the AI abundance problem a distributional form. Cheap answers can coexist with scarce inquiry opportunity if the conditions required for question formation and long-horizon attention remain concentrated.

18.5.8 Aesthetic Orientation

Aesthetic orientation concerns participation in practices of perception, making, interpretation, judgment, and appreciation through which subjects encounter qualities that are not exhausted by instrumental usefulness. Chapter 17 treated aesthetic judgment as one source of epistemic orientation under incomplete explicit criteria. The present subsection broadens the participatory question while retaining the chapter's economic scope.

Artificial systems can generate images, music, prose, designs, simulations, and other symbolic materials at high volume. Symbolic abundance changes the conditions under which aesthetic participation occurs. Production costs can fall, entry into some practices can widen, and new hybrid forms can emerge. At the same time, attention, provenance, situated interpretation, communities of practice, embodied technique, and the cultivation of taste can remain scarce. Dewey's account of art as experience is useful because it links aesthetic experience to participation, perception, doing, undergoing, and continuity within experience rather than locating value only in detachable objects (Dewey 1934).

Definition 18.69 (Aesthetic participation capacity). *Aesthetic participation capacity* is the practical ability of a subject to enter, sustain, interpret, create within, and revise a relation to aesthetic practices or objects through which perception, judgment, expression, or shared cultural meaning can develop.

The definition permits artificial tools to become part of aesthetic participation without treating generated output volume as a measure of aesthetic capacity. A person can use generative systems to explore form, compare styles, prototype ideas, or overcome technical barriers while still exercising situated judgment. Another configuration can narrow participation when platforms optimize toward recurrent styles, opaque rankings, or rapid consumption while weakening opportunities for practice and interpretation.

Proposition 18.70 (Symbolic abundance and aesthetic participation). *An increase in generated symbolic material expands aesthetic participation when it also enlarges practical opportunities for perception, interpretation, making, judgment, attribution, and community engagement; output abundance alone leaves those participatory capacities underdetermined.*

This distinction prepares later analysis of symbolic abundance and representation in Section 18.11. The present concern is the subject-side capacity to participate in aesthetic orientation rather than the provenance and institutional verification of synthetic media.

18.5.9 Subjective Continuity beyond Employment

Employment often supplies a temporal narrative linking education, skill, occupational identity, colleagues, advancement, retirement, and accumulated recognition. AI-mediated labor transformation can disturb this continuity even where material support is maintained. The final subsection therefore examines the economic conditions through which subjects can sustain long-horizon continuity when employment becomes more intermittent, less central, or less available.

Chapter 17 defined subjective epistemic continuity through the relation between prior learning and present or future orientation. The present analysis expands the object beyond knowing. Subjective continuity can involve care commitments, artistic practice, civic membership, places, relationships, institutions, bodily capacities, craft, language, memory, research, spiritual practice, or other projects through which a person connects earlier and later stages of life. Economic arrangements affect this continuity through housing, health care, income security, time, mobility, access to institutions, preservation of records, recognition, and the ability to enter new roles after disruption.

Definition 18.71 (Post-employment subjective continuity). *Post-employment subjective continuity* is the capacity of a subject to connect remembered commitments, capabilities, relations, and projects with revisable present and future participation when paid employment provides only part, or little, of the temporal and social structure of life.

Continuity in Definition 18.71 does not require preserving one identity unchanged. A person can change vocation, community, location, skills, commitments, or modes of participation while retaining enough historical connection to interpret the change as part of an intelligible life trajectory. Institutions can support such revision by preserving access to learning, care, cultural practice, public participation, personal records, and material security during transitions.

Proposition 18.72 (Existential-participation architecture). *When employment ceases to bundle income, recognition, learning, social connection, contribution, and temporal continuity reliably, a viable participation architecture requires these functions to be made available through a plurality of institutions and relations whose access does not depend exclusively on labor-market demand.*

Proposition 18.72 identifies an institutional design problem rather than selecting one arrangement. Adequacy depends on practical access, recognition, agency, sustainability, pluralism, and the distribution of power over entry and continuation. Section 18.6 turns next to ownership of productive intelligence because control over models, compute, data, platforms, and access helps condition how such participation arrangements can be financed and governed.

18.6 Ownership of Productive Intelligence

This section develops the ownership architecture of artificial productive capacity. Its role is to identify how recognized claims, effective control, use rights, exclusion, access, governance, and transfer are distributed across the model, compute, data, plat-

form, and infrastructure layers through which artificial capability becomes economically operative. The objective is narrower than a general legal theory of artificial intelligence and broader than ownership of model weights alone. The analysis asks which positions can mobilize productive intelligence, set the terms of its use, exclude or condition others, redirect its development, and participate in the returns generated through it. The discussion proceeds through model ownership, compute ownership, data control, platform control, infrastructure control, access rights, public and commons models, and distributed ownership. The method extends Chapter 12's ownership-control distinction and the capability-to-power analysis of Section 18.3. Ownership is treated as one historically situated architecture through which capability can be organized; effective control and relational power require separate identification.

Artificial productive capacity was defined in Section 18.1 as capability embedded in a coupled configuration of models, compute, data, energy, interfaces, organizations, rules, and complementary human capacities. Ownership analysis should therefore follow the same relational decomposition. A party can own model weights while renting compute, relying on third-party distribution, licensing data, and operating under access conditions imposed elsewhere. Another party can own little of the underlying stack while controlling a high-leverage interface through which many users reach it. A public institution can finance an open model while private firms supply the compute and deployment infrastructure. These configurations allocate different rights, dependencies, revenues, risks, and capacities for revision.

The property-rights literature provides a useful starting discipline because ownership can be decomposed into differentiated bundles of claims rather than represented as a single binary status (Schlager and Ostrom 1992). The incomplete-contract tradition similarly emphasizes the economic significance of residual control when future uses cannot be completely specified in advance (Grossman and O. D. Hart 1986; O. Hart and Moore 1990). GRE does not import either framework as a complete theory of AI ownership. Their relevance here is methodological: a statement that an organization “owns the AI” can conceal distinct relations concerning model artifacts, compute, data, deployment, access, adaptation, revenue, governance, and later disposition.

Definition 18.73 (Productive-intelligence ownership architecture). A *productive-intelligence ownership architecture* is the historically situated configuration of recognized claims, effective control relations, use and access rights, exclusion capacities, governance powers, responsibilities, transfer conditions, and benefit claims distributed across the model, compute, data, platform, infrastructure, and organizational layers through which artificial productive capability is generated and mobilized.

Definition 18.73 makes the stack rather than a single artifact the primary object of inquiry. It also keeps legal title, practical control, and relational power distinct. A recognized owner can have weak practical control over a model when deployment depends on another provider's compute or platform. A non-owner can exercise consequential control through licensing terms, technical interfaces, financing, standards, or access gates. Section 18.3 supplies the additional mechanism-sensitive test required before such control is interpreted as relational power.

Table 18.6 summarizes the principal ownership and control layers examined in

Table 18.6: Ownership and control layers in artificial productive intelligence.

Layer	Principal ownership or control relations	Economic consequence requiring analysis
Model	Title, licensing, modification, derivative use, deployment authority, release conditions	Who can reproduce, adapt, withhold, specialize, or redirect modeled capability
Compute	Hardware ownership, leasing, cloud allocation, scheduling, cluster administration	Who can realize capability at relevant scale, latency, reliability, and cost
Data	Collection, custody, permission, provenance, curation, feedback, deletion, portability	Who can train, update, evaluate, personalize, audit, or improve systems through data
Platform	Interface control, distribution, ranking, identity, payment, default integration, API terms	Who mediates users, applications, demand, visibility, and downstream dependence
Infrastructure	Energy, semiconductor supply, networks, storage, cloud, security, deployment systems	Which complementary bottlenecks condition continuity and substitutability of capability
Access rights	Use, inspect, adapt, fine-tune, deploy, export, redistribute, terminate, contest	Which practical capabilities are available to differently positioned participants
Public or commons arrangements	Public provision, shared stewardship, open resources, contributor governance, maintenance	How broad access, collective governance, sustainability, and public purpose are organized
Distributed ownership	Layered, cooperative, federated, trust-like, member, public-private, or multi-party claims	How authority, risk, residual benefit, and revision capacity are distributed across the stack

this section. The layers can be held by different subjects and can change at different rates.

The table also anticipates Section 18.7. Ownership matters for surplus because the positions that hold residual claims, determine access terms, or control complementary bottlenecks can participate differently in the returns generated by artificial productive capacity. The present section establishes the ownership architecture before the subsequent section analyzes those returns.

18.6.1 Model Ownership

Model ownership concerns claims over the computational artifacts and associated resources through which a trained system's capability is represented, reproduced,

modified, or deployed. Depending on the system and institutional arrangement, the relevant objects can include model weights, source code, training and inference software, configuration files, adaptation layers, evaluation assets, deployment packages, technical documentation, trademarks, contractual rights, or combinations of these. The applicable legal status can differ across jurisdictions and objects. GRE therefore begins with the operative economic relations rather than assuming that the word *model* denotes one legally uniform asset.

A model can also be economically divisible in ways that ordinary ownership language obscures. One organization can hold recognized rights in model weights, another can control the software needed to serve them efficiently, and downstream users can receive only an interface-level permission to invoke the system. Fine-tuned derivatives can introduce additional claims and dependencies. A released weight file can be reproducible while later versions, safety layers, optimization tooling, or high-quality evaluations remain controlled elsewhere. Model ownership should therefore be represented as a profile of actionable positions rather than a yes–no attribute.

Definition 18.74 (Model-ownership profile). *A model-ownership profile records, for a specified artificial system, the recognized claims and practical capacities concerning possession or custody of model artifacts, reproduction, modification, derivative construction, deployment, licensing, exclusion, transfer, version control, and participation in residual economic returns.*

The definition permits several profiles to coexist over one model family. A foundation can fund development, a corporation can hold commercial rights, researchers can possess a research-use copy, cloud providers can host deployments, and users can receive limited invocation rights. The economic significance of each position depends on what the holder can actually do and on which complementary resources remain necessary.

Proposition 18.75 (Model ownership–productive control non-equivalence). *Recognized ownership of a model artifact establishes productive control only to the extent that the owner can mobilize the complementary compute, data, software, permissions, infrastructure, and organizational capacities required for the economically relevant use. Productive control can also arise through those complementary layers without ownership of the underlying model artifact.*

Proposition 18.75 specializes the ownership–control non-equivalence established in Chapter 12. It also clarifies why transfer of model weights can materially widen some forms of access while leaving other forms of control concentrated. The practical question is which operations become available after the transfer and which still depend on external relations.

18.6.2 Compute Ownership

Artificial capability becomes productive through computation performed on physical and organizational infrastructures. Compute ownership therefore concerns more than possession of processors. Economically relevant positions can include title to accelerators and servers, long-term leases, reserved cloud capacity, priority scheduling, cluster administration, access to high-bandwidth interconnects, storage, cooling, energy supply, maintenance, and the engineering capacity required to operate the sys-

tem. Ownership and practical availability can diverge because hardware that exists physically may be unavailable at the time, scale, location, reliability, or cost required by a particular workload.

Compute also enters different stages of the capability lifecycle. Training, adaptation, evaluation, simulation, batch inference, low-latency serving, and agentic workloads can require different configurations. A subject with sufficient inference access to use an existing model may remain unable to train a replacement, reproduce an experiment, run a large-scale evaluation, or maintain service under demand spikes. The economically relevant unit is therefore the relation between computational resources and the operations they enable.

Definition 18.76 (Compute ownership and availability profile). *A compute ownership and availability profile records the recognized claims, contractual positions, scheduling authority, operational control, scale, duration, location, reliability, cost conditions, and substitution possibilities through which computational resources can be mobilized for specified artificial-intelligence operations.*

This profile distinguishes ownership of equipment from a practically adequate compute position. A firm can own a small cluster while relying on external capacity for frontier-scale workloads. A university can obtain temporary access through grants or national infrastructure. A cloud customer can hold no hardware title while possessing contractually protected capacity for a defined period. These positions create different horizons for experimentation, deployment, bargaining, and resilience.

Proposition 18.77 (Compute-realization condition). *A model-level capability becomes economically realizable at a specified scale only where the relevant configuration can mobilize sufficient computational capacity together with the complementary energy, networking, storage, software, and operational support required by that use.*

The proposition identifies compute as a conversion layer between technical capability and productive capacity. It does not imply that compute is the sole bottleneck or that greater compute always yields greater economic value. The limiting layer can move as models, algorithms, hardware, organizational practice, and downstream demand change.

18.6.3 Data Control

Data require a different vocabulary because the relevant economic relation is frequently control rather than a unitary ownership status. Training corpora, licensed datasets, public records, proprietary operational data, user interactions, sensor streams, annotations, feedback, evaluations, synthetic data, and derived statistics can carry different permissions, stewardship obligations, privacy constraints, provenance structures, and technical dependencies. A single claim of “data ownership” can therefore obscure the relations that determine who may collect, retain, combine, inspect, update, delete, transfer, monetize, or use data to alter an artificial system.

Data control is also historically generative. Deployment can create new interaction records, error traces, preference data, domain examples, and evaluation feedback. A provider with a large installed user base can therefore acquire a continuing stream of material that supports model improvement, product adaptation, safety analysis,

personalization, or market intelligence. The consequence depends on the quality and relevance of the data as well as on the ability to convert it into capability.

Definition 18.78 (AI data-control position). An *AI data-control position* is the configuration of collection, custody, access, combination, curation, provenance, retention, deletion, portability, training, evaluation, feedback, and transfer capacities through which a subject or institution can condition the use of data in the generation, adaptation, assessment, or deployment of artificial capability.

The definition includes responsibilities and restrictions because control can be constrained as well as enabling. A custodian can be required to preserve confidentiality, a public repository can impose use conditions, a community can retain stewardship authority, and an organization can have technical possession while lacking permission for a proposed use. These relations affect the practical possibility of capability generation.

Proposition 18.79 (Data–capability conversion condition). A *data-control advantage* contributes to *productive-intelligence advantage* when the controlled data are materially relevant to a capability or deployment objective and the controlling configuration possesses the complementary compute, models, methods, permissions, and organizational capacity required to convert those data into improved or differentiated productive capability.

Proposition 18.79 prevents data volume from functioning as an automatic proxy for advantage. Large quantities of poorly matched, low-quality, legally unusable, inaccessible, or weakly interpretable data can have limited productive effect. Smaller domain-specific datasets can become highly consequential when they connect to an important application and a strong conversion pipeline.

18.6.4 Platform Control

Platforms mediate the relation between artificial capability and users, developers, organizations, markets, and institutional processes. Relevant platform layers can include conversational interfaces, application stores, developer APIs, enterprise integration systems, identity services, payment systems, workflow software, marketplaces, search and ranking systems, distribution channels, and default integrations. A platform can therefore exercise economically consequential control even when it does not own every model or infrastructure layer that supports its service.

Platform control is especially important because it can organize discovery and default use. Users often encounter a model through an interface that determines which version is presented, which tools are available, what usage limits apply, how outputs can be exported, how data are retained, which downstream services can connect, and what prices or contractual terms apply. Developers can face similar conditions through APIs, application review, rate limits, technical standards, or marketplace policies. These mechanisms make the platform a conversion interface between upstream capability and downstream participation.

Definition 18.80 (AI platform-control interface). An *AI platform-control interface* is a set of technical, contractual, ranking, identity, payment, interoperability, and governance mechanisms through which a platform conditions the discovery, invocation,

integration, distribution, monetization, or continued use of artificial capability by downstream participants.

A platform-control interface can widen participation by reducing transaction costs, providing common tooling, handling security, or connecting small developers to users. It can also create dependence when downstream participants cannot readily substitute another interface, preserve accumulated data, transfer integrations, reach users elsewhere, or contest rule changes. The stronger power diagnosis remains governed by Section 18.3.

Proposition 18.81 (Platform mediation condition). *Platform control becomes economically consequential for productive intelligence when changes in platform rules, defaults, rankings, interfaces, prices, or interoperability materially change which artificial capabilities downstream participants can access, combine, distribute, or sustain.*

The proposition makes platform ownership one possible source of control while leaving room for contractual, regulatory, technical, or standards-based constraints on platform discretion. It also preserves the possibility that users and developers can exercise countervailing capacity through multi-homing, interoperability, alternative distribution, collective governance, or public infrastructure.

18.6.5 Infrastructure Control

Infrastructure control concerns the shared substrates on which models, compute, data, and platforms depend. Section 17.11 treated epistemic infrastructure as the shared technical and organizational substrate of epistemic activity. Artificial productive intelligence adds further dependencies involving semiconductor fabrication and supply, electricity, cooling, data centers, cloud services, telecommunications, storage, cybersecurity, identity systems, specialized software, payment systems, physical facilities, and logistics. Some infrastructures are general-purpose resources used across many sectors; others are specialized around computational production.

Infrastructure matters because ownership at one visible layer can be conditioned by dependencies at another. An organization can own a model and possess data while relying on external cloud infrastructure. A compute provider can own hardware while depending on energy supply, chip vendors, network connectivity, and specialized maintenance. A public model can remain difficult to deploy where the complementary infrastructure is scarce. The ownership architecture of productive intelligence is therefore vertically and horizontally coupled.

Definition 18.82 (Productive-intelligence infrastructure-control stack). *A productive-intelligence infrastructure-control stack is the layered configuration of control, access, substitution, maintenance, and continuity relations across the physical, computational, network, energy, software, security, and organizational infrastructures required to generate or sustain a specified artificial productive capability.*

Frischmann's analysis of infrastructure is useful here because shared infrastructural resources can enable heterogeneous downstream activities whose social value exceeds the direct value captured by the infrastructure provider (Frischmann 2012). For GRE, the additional question concerns how access to such shared inputs changes

later generative possibilities across differently positioned subjects.

Proposition 18.83 (Multi-layer bottleneck condition). *Control over one infrastructural layer becomes a binding constraint on productive intelligence when adequate substitutes or bypasses are unavailable and practical use of the relevant capability depends materially on continued access to that layer. The binding layer can shift as technologies, institutions, prices, and alternative infrastructures change.*

This proposition makes bottleneck status relational and historical. A scarce chip can cease to be binding after substitution or architectural change; a network standard can become more consequential as adoption increases; energy access can become decisive at large deployment scale even where model weights are widely available. Ownership analysis should therefore track the evolving dependency graph rather than freeze one layer as permanently foundational.

18.6.6 Access Rights

Access rights connect ownership architecture to practical capability. Access can include permission to invoke a model, inspect its outputs, retrieve logs, use an API, download weights, run a local copy, adapt parameters, fine-tune on local data, integrate tools, deploy commercially, redistribute derivatives, export accumulated state, or terminate use while preserving portability. These permissions are heterogeneous. A user with invocation access can remain unable to inspect, modify, reproduce, or migrate the system; another participant can have deep technical access while lacking commercial deployment rights.

Schlager and Ostrom's decomposition of property-rights positions is useful as a precedent for treating access, withdrawal, management, exclusion, and alienation as differentiated relations rather than one ownership binary (Schlager and Ostrom 1992). The objects differ in the present domain, yet the analytical lesson transfers: access to productive intelligence should be specified through the actual bundle of practical rights and restrictions.

Definition 18.84 (Productive-intelligence access bundle). *A productive-intelligence access bundle is the configuration of permissions, technical capabilities, restrictions, portability conditions, revocation rules, audit rights, adaptation rights, deployment rights, and contestation procedures through which a participant can use or reshape an artificial productive capability.*

The bundle can be broad in one dimension and narrow in another. Openly downloadable weights can support local deployment while commercial restrictions limit some uses. A paid service can provide powerful invocation while preserving little inspection or portability. An employee can have extensive operational access inside an organization while holding no transferable rights outside it. Public authorities can gain audit or reporting rights that ordinary users lack. The resulting configurations shape both productive capability and dependency.

Proposition 18.85 (Access–ownership non-equivalence). *Broad access to artificial productive capability can exist without ownership of the underlying model or infrastructure, while ownership can coexist with practically narrow access when complementary resources, permissions, interfaces, or institutional approvals are missing.*

The proposition has an important implication for capability equalization. Providing interface access to a model can reduce some task-level asymmetries while leaving adaptation, compute, data, interoperability, and institutional deployment rights unequal. Conversely, broad rights to inspect, adapt, and locally deploy a model can create significant independent capacity even where users hold no title to upstream infrastructure.

18.6.7 Public and Commons Models

Public and commons arrangements provide alternatives to concentrating the entire productive-intelligence stack in conventional private ownership. The term *public model* can refer to several distinct arrangements: publicly funded development, public ownership of model artifacts, publicly operated compute, public procurement with access conditions, public-interest licensing, or publicly accountable deployment. A commons arrangement adds shared resources together with governance relations through which a community organizes access, contribution, maintenance, revision, and stewardship. These arrangements can overlap while remaining analytically distinct.

Chapter 17 developed the knowledge commons as a governed shared epistemic configuration and distinguished commons governance from simple openness. Hess and Ostrom's work on knowledge commons provides a useful foundation for analyzing shared informational resources through institutional arrangements of access, preservation, enclosure, and collective governance (Hess and Ostrom 2007). Benkler's analysis of commons-based peer production likewise demonstrates that large-scale productive coordination can occur through distributed contribution structures that are not reducible to market pricing or managerial hierarchy (Benkler 2002). Productive intelligence extends these questions to computational resources whose maintenance and deployment can be materially intensive.

Definition 18.86 (Commons-governed productive intelligence). *Commons-governed productive intelligence* is an artificial productive-capability configuration in which a sufficiently identifiable community or public of participants shares specified model, data, compute, software, or infrastructure resources under governance arrangements that organize access, contribution, maintenance, revision, stewardship, conflict resolution, and continuity.

The definition is intentionally stronger than open availability. Publishing model weights can widen access while leaving governance, maintenance, compute, data, and future development concentrated. A commons can also use differentiated permissions when privacy, security, cultural stewardship, safety, or resource scarcity makes unrestricted access unsuitable. The institutional question concerns who participates in rule formation and how the generative conditions of the shared resource are reproduced.

Public and commons arrangements can also address infrastructural layers. Shared compute facilities can widen experimentation; public datasets can support research and service provision; community-governed models can preserve linguistic or domain-specific capacities; shared evaluation infrastructures can reduce duplication; and public procurement can attach interoperability or access conditions to

publicly financed systems. Each arrangement creates different obligations and risks. Public status by itself does not guarantee broad effective access, and commons governance can reproduce internal inequalities if participation, expertise, time, or infrastructure are unevenly distributed.

Proposition 18.87 (Openness–ownership architecture non-equivalence). *Open availability of one productive-intelligence layer does not determine the ownership architecture of the wider capability stack. Effective openness depends on the complementary rights, resources, maintenance structures, governance relations, and infrastructures required to mobilize and reproduce the capability.*

Proposition 18.87 parallels the openness analysis of Chapter 17. An open model can be productively inaccessible without adequate compute. Public compute can remain difficult to use without appropriate software or expertise. Open data can be unusable without provenance or permission for the intended purpose. The generative value of openness therefore depends on the architecture surrounding the open component.

18.6.8 Distributed Ownership

Distributed ownership refers to arrangements in which claims, governance powers, responsibilities, and residual benefits are allocated across several subjects or institutional forms rather than concentrated in one owner of the entire productive-intelligence stack. Distribution can occur vertically across layers, horizontally among co-owners, or functionally across differentiated rights. Examples include cooperatives, federations, trusts, public–private arrangements, member-owned infrastructures, multi-stakeholder organizations, joint ventures, layered licensing, community stewardship, and combinations of public, private, and commons governance.

Distributed ownership should be distinguished from fragmented control without coordination. Several firms can own different layers while one bottleneck remains decisive. A nominally cooperative arrangement can delegate substantial operational authority to specialized managers or infrastructure providers. A public–private system can distribute formal claims while practical dependence remains concentrated. Conversely, a configuration with a strong central service provider can retain meaningful distributed governance where users possess enforceable portability, audit, representation, or exit rights. The relevant question is how the distribution of rights maps onto effective capability and future revision.

Definition 18.88 (Distributed productive-intelligence ownership architecture). A *distributed productive-intelligence ownership architecture* is a configuration in which ownership-related claims, governance authority, access rights, responsibilities, residual benefits, and revision capacities over the artificial productive-capability stack are allocated across multiple subjects or institutional forms according to an explicit or historically stabilized rule structure.

The definition does not attach an automatic normative advantage to distribution. Distribution can widen participation and reduce single-point dependency; it can also create coordination costs, ambiguous responsibility, fragmented maintenance, strategic hold-up, or internal power asymmetries. Evaluation therefore requires attention to the consequences generated by the specific allocation of rights and control.

Proposition 18.89 (Distributed-ownership effectiveness condition). *Distributed ownership materially redistributes productive-intelligence capacity when the distributed claims are connected to practical access, governance influence, revision capability, credible alternatives, and participation in residual benefits across the layers that are consequential for the relevant use. Formal dispersion of title alone leaves effective control underdetermined.*

This condition also connects ownership to power without collapsing the two. A distributed architecture can reduce some dependency mechanisms while generating others. Cooperative model governance can still depend on concentrated cloud compute. Public infrastructure can broaden access while relying on proprietary software. Multi-party ownership can create veto positions whose power depends on the alternatives available to others. These relations should be analyzed through the conversion mechanisms developed in Section 18.3.

The section yields three conclusions for the remainder of Chapter 18. First, productive intelligence has no single ownership locus at the level relevant to GRE; economically consequential claims and control relations are distributed across a layered capability stack. Second, ownership, control, access, governance, and power are related but non-equivalent, so each requires separate reconstruction. Third, the architecture of residual claims and access conditions helps determine how gains from artificial productive capacity are distributed and reinvested. Section 18.7 therefore turns to AI-generated surplus, asking how productivity gains and rents arise, who can capture them, and how their allocation can affect future generative capacity.

18.7 AI-Generated Surplus

This section develops the distributional and generative analysis that follows from artificial productive capacity and its ownership architecture. Its role is to distinguish gains generated through AI-mediated production from the institutional processes through which those gains become prices, wages, profits, rents, public revenue, retained capability, time release, or other economically consequential returns. The objective is to identify where an AI-related surplus can arise, how claims on that surplus become concentrated, and how allocation can either reproduce existing capability asymmetries or enlarge later generative capacity. The discussion proceeds through productivity gains, surplus concentration, returns to model ownership, returns to infrastructure, redistribution, generative allocation, social investment, and recirculation. The method is relational and baseline-sensitive. It treats surplus as a historically situated remainder or advantage relative to a declared comparison configuration, while preserving heterogeneous value and avoiding a universal scalar measure of economic gain.

The analysis inherits three distinctions from the preceding sections. Section 18.4 separated task productivity, employment, income, contribution, and participation. Section 18.6 separated ownership, effective control, access, governance, and power across the productive-intelligence stack. Section 18.3 established that capability and ownership positions become power-relevant through identifiable conversion mechanisms. These distinctions are necessary because the same technical productivity im-

provement can generate very different social and economic outcomes under different ownership, bargaining, pricing, taxation, access, and institutional arrangements. Korinek and Stiglitz similarly show that AI-related technological change can affect factor prices, innovation rents, distribution, and employment through several channels under specified economic conditions (Korinek and Stiglitz 2019). GRE extends the inquiry by asking how the resulting returns alter the future generative capacities of the positions participating in, benefiting from, or excluded from the production process.

Definition 18.90 (AI-generated surplus). An *AI-generated surplus* is an economically consequential gain attributable, under a declared comparison and dependence account, to the incorporation of artificial productive capacity into a productive configuration after the analysis has specified the relevant baseline, complementary inputs, reproduction costs, and retained output dimensions. The gain can appear in heterogeneous forms, including additional output, reduced resource use, quality improvement, time release, lower prices, residual income, rents, public revenue, expanded service capacity, or increased future productive capability.

Definition 18.90 uses *surplus* as a broad analytical category whose local specification can take accounting, welfare, political-economic, or institutional forms. A domain-specific analysis should state the assumptions and measurement rules that determine its narrower use. The GRE-level object records the extra economic possibility generated relative to a declared baseline and then asks how that possibility is realized, claimed, converted, and recirculated.

Table 18.7 supplies the section's organizing architecture. The same monetary flow can occupy several rows depending on its relational role. A payment to a model provider can compensate current service, yield a residual return to ownership, finance infrastructure, and support later capability expansion. A tax on that payment can become redistribution or social investment. A reduction in working time can realize part of the productivity gain as released human time rather than monetary income. The analysis therefore follows mechanisms and consequences, allowing the classification of an observed transfer to depend on its relational role.

18.7.1 Productivity Gains

Artificial productive capacity can produce gains through several channels: faster execution of a retained task, substitution of computational for human or material inputs, improved quality at similar cost, greater output from a fixed resource base, expanded service availability, reduced coordination cost, accelerated search, or creation of previously infeasible products and processes. Empirical studies of generative-AI assistance already demonstrate productivity changes in bounded professional settings, while the longer-run organization of those gains remains open (Noy and Zhang 2023; Brynjolfsson et al. 2025). Acemoglu and Restrepo's task framework is also relevant because productivity change can coexist with displacement, new-task creation, and changing labor demand across different operations within an occupation (Acemoglu and Restrepo 2019).

A GRE analysis requires an explicit comparison configuration. Let the baseline identify the retained task, quality standard, resource conditions, temporal horizon,

Table 18.7: Analytical dimensions of AI-generated surplus. The dimensions distinguish generation of an economic gain from the institutional pathways through which the gain is claimed, allocated, and returned to later production.

Dimension	Primary analytical question	Generative implication
Productivity gain	Which output, quality, time, or resource-use relation changes relative to the declared baseline?	Creates additional economic possibility whose realized form remains institutionally open
Surplus concentration	Which positions obtain residual claims or repeated advantages from the generated gain?	Can reinforce capability, ownership, and bargaining asymmetries across later histories
Model return	Which returns are connected to rights or control over model assets and model-mediated services?	Can finance model improvement while also strengthening dependence on model-controlling positions
Infrastructure return	Which returns accrue to compute, energy, network, cloud, fabrication, or deployment bottlenecks?	Can make complementary infrastructure a decisive site of accumulation even when models are widely available
Redistribution	Which generated claims are transferred after or during initial allocation?	Can alter material access while leaving some ownership, control, and participation structures unchanged
Generative allocation	Which uses of surplus expand later capacities, relations, alternatives, or resilience?	Connects current gain to future generative opportunity without assuming one universal value metric
Social investment	Which shared capabilities and infrastructures receive sustained resources?	Can broaden education, care, knowledge, public capacity, commons, and other long-horizon generative conditions
Recirculation	Which returns flow back into the relations and capacities that sustain future generation?	Determines whether surplus reinforces narrow accumulation, supports wider reproduction, or dissipates from the generative system

and complementary infrastructure. A gain observed after AI incorporation is meaningful only relative to those conditions. A tenfold increase in generated drafts, for example, has a different economic meaning when verification costs rise sharply than when verification requirements remain constant. A reduction in labor time can become a productivity gain while also increasing dependence on model access. A faster decision-support process can reduce delay while creating new audit and contestability costs. Gross technical improvement therefore requires a relational account of the additional inputs and constraints through which the improvement becomes economically usable.

Definition 18.91 (AI-mediated productivity gain profile). An *AI-mediated productivity gain profile* specifies the changes, relative to a declared baseline, in economically relevant output quantity, output quality, required human time, required compute and material resources, coordination burden, verification burden, latency, and future capability associated with incorporation of artificial productive capacity into a production configuration.

The profile is intentionally multidimensional. Some components can improve

while others deteriorate. A system can reduce drafting time while increasing review burden; expand service volume while consuming more energy; improve average performance while increasing tail-risk exposure; or release human time while reducing opportunities for skill formation. The economic assessment therefore depends on which dimensions matter for the application and how their heterogeneous consequences are evaluated.

Proposition 18.92 (Productivity–surplus realization non-equivalence). *An improvement in an AI-mediated productivity gain profile establishes additional productive possibility relative to the declared baseline. The realized surplus remains dependent on pricing, ownership, bargaining, demand, complementary scarcity, verification, institutional rules, and the disposition of released time or resources.*

Proposition 18.92 explains why measured productivity does not determine distribution. A gain can be passed to users through lower prices, retained as profit, shared through wages, transformed into shorter working time, absorbed by higher quality standards, allocated to public revenue, or dissipated through new costs and competitive expenditure. The next subsections study the structures that influence these realizations.

18.7.2 Surplus Concentration

Surplus concentration concerns the distribution of repeated claims on AI-generated gains. Concentration can arise at several layers. Model developers can receive licensing or service revenue. Compute providers can receive returns from scarce processing capacity. Platform operators can retain transaction or distribution margins. Firms incorporating AI can receive profits from cost reductions. Workers can receive higher wages or bonuses where bargaining and complementary skill structures support them. Consumers can receive lower prices or higher-quality services. Governments can receive tax revenue. Communities can receive little direct return even where their data, labor, institutions, or cultural resources contributed to the capability stack.

The relevant concentration object is therefore broader than a snapshot of income inequality. A position that captures residual claims can use them to purchase additional compute, acquire data, recruit expertise, subsidize distribution, finance lobbying, shape standards, or withstand periods of low prices. Current surplus can consequently alter the capability and power architecture that conditions later surplus generation.

Definition 18.93 (AI-surplus concentration profile). *An AI-surplus concentration profile describes the distribution of claims on AI-generated gains across the subjects and institutional positions retained by an analysis, together with the duration, convertibility, and reinvestment capacities attached to those claims.*

The profile includes more than monetary shares. A recurring right to preferential compute, proprietary improvement data, distribution access, or strategic information can function as a surplus-bearing advantage even when immediate cash flow is modest. Conversely, a large one-time payment can have limited long-run effect when it creates little durable capability or bargaining power.

Proposition 18.94 (Surplus–capability feedback condition). *Where concentrated AI-generated surplus can be converted into complementary assets or institutional positions that raise later productive capability, access, or control, current surplus concentration can contribute generatively to later capability asymmetry and to the ownership or power structures through which subsequent surplus is allocated.*

The proposition states a conditional feedback mechanism whose strength depends on the surrounding competitive and institutional configuration. Competitive entry, taxation, interoperability, public infrastructure, commons provision, technological diffusion, or changing demand can weaken the loop. The analytical point is that surplus allocation participates in the history of capability formation, so evaluation should include both terminal distribution and its effects on later capability.

18.7.3 Returns to Model Ownership

Model ownership creates one possible claim on AI-generated surplus. The magnitude and persistence of that claim depend on the rights and control structures developed in Section 18.6: exclusion, licensing, modification, distribution, deployment, adaptation, and access to model improvements can each generate different return pathways. A proprietary model can support recurring service revenue; an openly available model can support complementary service revenue; a model embedded in a platform can generate indirect returns through distribution, advertising, data, or ecosystem dependence.

Model returns should be decomposed into compensation for current resource use, recovery of development and maintenance costs, risk-bearing returns, scarcity rents, and returns connected to strategic control where the evidence permits such distinctions. GRE does not require one universal allocation among these categories. It does require the analyst to avoid treating every payment to a model-controlling position as evidence of rent or power.

Definition 18.95 (Model-return profile). *A model-return profile specifies the monetary and non-monetary returns associated with ownership, licensing, control, maintenance, improvement, or distribution of a model asset, together with the rights, costs, complementary resources, and competitive conditions through which those returns are realized.*

A model-return profile can include subscription revenue, API payments, licensing fees, equity appreciation, improvement data, ecosystem adoption, reputational gains, and strategic access to downstream demand. These forms have different implications for later productive capacity. Improvement data can increase future model quality; ecosystem adoption can reduce switching; revenue can finance compute; reputational gain can attract complementary labor or capital.

Proposition 18.96 (Model-rent identification condition). *A model-related return is identified as an economic rent only after the analysis specifies the relevant scarcity or exclusion mechanism, the comparison return under the declared counterfactual, and the institutional conditions that permit the excess return to persist. Ownership status or high profitability alone leaves the rent claim underdetermined.*

This condition keeps surplus analysis compatible with the power discipline estab-

lished earlier. A return can be high because a model produces substantial value under competition; another can persist because interoperability barriers, exclusive data, contractual restrictions, or platform integration limit alternatives. The mechanisms can coexist and require separate evidence.

18.7.4 Returns to Infrastructure

The ownership analysis in Section 18.6 showed that productive intelligence depends on a layered infrastructure stack. Surplus can therefore accrue at complementary layers even when model ownership is dispersed. Compute clusters, semiconductor fabrication, cloud orchestration, energy supply, high-bandwidth networks, secure data environments, deployment systems, and specialized technical services can each become return-bearing positions where their capacity is scarce or difficult to substitute.

Infrastructure returns are analytically important because rapid model diffusion can relocate scarcity. If several organizations can obtain comparable model weights while only a small subset can train, adapt, or serve them at required scale, the decisive residual return can move toward compute or deployment infrastructure. Conversely, abundant compute can shift the bottleneck toward data, distribution, regulation, trust, or domain-specific integration. Surplus location is therefore endogenous to the evolving productive stack.

Definition 18.97 (AI-infrastructure return profile). *An AI-infrastructure return profile specifies the returns associated with providing, owning, governing, or controlling the complementary physical and digital infrastructures required to realize artificial productive capacity, together with the scarcity, capacity, substitutability, and access conditions governing those returns.*

Proposition 18.98 (Bottleneck-return relocation condition). *When one layer of the productive-intelligence stack becomes more substitutable while another complementary layer remains capacity-constrained or difficult to replace, part of the residual return generated by AI-mediated production can relocate toward the less substitutable layer, subject to bargaining and institutional conditions.*

The proposition helps explain why analysis of AI surplus should follow the whole productive architecture. Model capability can improve while the strategic economic return accrues to energy, chips, cloud services, distribution channels, or domain-specific organizations. The resulting allocation can in turn finance expansion of the bottleneck layer and reshape later dependency.

18.7.5 Redistribution

Redistribution modifies claims on AI-generated surplus through taxes, transfers, social insurance, public provision, collective bargaining, revenue-sharing arrangements, mandated contributions, or other institutional mechanisms. It can reduce material consequences of concentrated initial claims and can convert private returns into public or shared resources. The scope of this subsection is deliberately bounded because Section 18.8 examines redistribution and its limits in detail. The present task is to locate redistribution inside the surplus architecture.

The distinction between initial allocation and redistribution matters. Ownership,

pricing, bargaining, labor contracts, access rights, competition rules, procurement, and public ownership influence the distribution generated inside production itself. Tax-and-transfer systems can subsequently alter disposable claims. Some institutions operate at both stages. Collective bargaining can affect wages before profits are realized; public equity participation can create an initial public residual claim; a tax can reallocate income after realization. GRE therefore treats the temporal label *redistribution* as one part of a broader allocation history.

Definition 18.99 (AI-surplus redistribution profile). *An AI-surplus redistribution profile specifies the institutional mechanisms through which initially realized claims on AI-generated surplus are reassigned, pooled, socialized, or converted into shared provision, together with the recipients, conditions, timing, and capability effects of those transfers.*

Material transfers can expand effective freedom by improving access to resources and opportunities, consistent with the capability-oriented emphasis on substantive opportunity developed by Sen (Sen 1999). Yet a transfer can leave control of models, infrastructures, work organization, or decision systems unchanged. It can also create new capabilities when used for education, health, mobility, compute access, or public infrastructure. The generative effect depends on the use and institutional setting of the transferred claim.

Proposition 18.100 (Redistribution–structural transformation non-equivalence). *Redistribution of realized AI-generated surplus can change material access and capability formation while leaving some antecedent ownership, control, dependency, and participation structures intact. Structural transformation requires additional mechanisms directed at the relevant relations.*

Proposition 18.100 motivates the separation between §427 and §428. Redistribution can be indispensable under concentrated gains and employment disruption while remaining insufficient as a complete account of participation, power, or ownership.

18.7.6 Generative Allocation

Generative allocation evaluates the use of surplus through its effects on future capacities, relations, alternatives, and conditions of value generation. The concept builds on the allocation framework developed in Chapters 13–14. An AI-generated gain can finance current consumption, shareholder distributions, compute expansion, education, research, care, ecological restoration, public infrastructure, cultural activity, or many other uses. These allocations have different temporal and relational consequences even when their immediate monetary value is similar.

Generative allocation does not supply a universal instruction to maximize future output. GRE retains heterogeneous values and the possibility that present well-being, rights, care, preservation, leisure, or ecological limits justify allocations whose value is poorly represented by a growth metric. The concept asks which later possibilities are created, preserved, foreclosed, or redistributed by an allocation and whose generative capacities are affected.

Definition 18.101 (Generative allocation of AI surplus). *A generative allocation of AI*

surplus is an allocation of claims or resources generated through AI-mediated productive gains that is evaluated partly through its effects on later capacities, relations, infrastructures, alternatives, and opportunities for heterogeneous value generation across the affected relational system.

This definition permits several scales. A firm can allocate surplus to worker training, model improvement, resilience, or dividends. A government can allocate revenue to public services, research, income support, or digital infrastructure. A community can allocate shared resources to local knowledge, care, culture, or common facilities. A household can allocate released time toward care, learning, rest, or civic participation. Generativity is evaluated through the consequence structure across institutional sectors.

Proposition 18.102 (Heterogeneous generative-allocation condition). *Evaluation of generative allocation requires the relevant future effects to remain distinguishable when they concern heterogeneous values, subjects, scales, or time horizons. Aggregation into a single return measure requires an independently justified conversion rule.*

The proposition preserves the book's treatment of heterogeneous value. A research investment can increase epistemic capacity while an ecological investment preserves environmental conditions and a care investment sustains relational continuity. Their contributions can interact without becoming commensurable by default.

18.7.7 Social Investment

Social investment denotes an institutional commitment of current resources to shared capabilities and conditions whose benefits can extend across persons, organizations, communities, and future histories. In an AI-rich economy, the category is especially relevant where private productive capacity grows rapidly while complementary human, public, or commons capacities remain scarce. Education, health, care, research, libraries, public compute, digital access, civic institutions, ecological resilience, cultural preservation, and community infrastructure can all become sites through which current surplus supports later generation.

The concept should remain broader than a narrow human-capital return calculation. Some investments matter because they increase productivity; others matter because they support substantive participation, public reasoning, care, ecological continuity, cultural plurality, or the ability to contest and govern powerful systems. Knowledge commons and commons-based peer production also demonstrate that shared resources and distributed contribution can sustain productive activity through institutional forms beyond conventional private ownership (Hess and Ostrom 2007; Benkler 2002). AI-generated surplus can therefore support public and commons capability as well as privately owned productive intelligence.

Definition 18.103 (AI-surplus social investment). *AI-surplus social investment* is the commitment of resources derived from AI-generated surplus to shared or broadly accessible capacities, institutions, infrastructures, relations, or commons whose expected significance includes the support of future participation, resilience, learning, care, knowledge, public capability, or heterogeneous value generation.

Social investment can be publicly funded, collectively governed, privately en-

dowed, cooperative, or hybrid. Its generative significance depends on accessibility, maintenance, governance, time horizon, and relation to existing inequalities. A publicly funded facility with high practical barriers can have weak distributive reach. A shared model can have limited usefulness without compute or expertise. A training program can raise individual capability while leaving institutional demand absent. Evaluation therefore requires attention to the full conversion chain from investment to effective capacity.

Proposition 18.104 (Social-investment conversion condition). *Resources allocated as social investment enlarge shared generative capacity when institutions and complementary conditions permit the funded resources to become practically accessible capabilities, durable relations, maintained infrastructures, or viable future alternatives for the intended participants.*

The proposition places conversion at the center of evaluation and treats expenditure volume as only one input to that conversion process. It also links social investment to the capability-equalization limits discussed in Section 18.2. Funding access to one layer can leave other bottlenecks intact; effective investment follows the relational path through which resources become capabilities.

18.7.8 Recirculation

Recirculation concerns the return of surplus-derived resources to the relations and capacities that support later generation. The concept is broader than reinvestment by an owner. Reinvestment can increase the productive capacity of the same firm or asset-owning position. Recirculation asks how returns move through the wider relational system: toward workers and contributors, users, communities, public institutions, commons, ecological supports, knowledge infrastructures, complementary industries, or future generations.

The distinction is important because several recirculation patterns are possible. A concentrated surplus can be reinvested primarily in compute and model improvement, creating a self-reinforcing capability loop. Part can circulate through wages and purchasing power, supporting demand and household capability. Tax revenue can finance public services. Lower prices can diffuse gains to users. Open-source contributions can return improvement to a shared technical commons. Released human time can be recirculated into care, learning, research, culture, or civic participation. Environmental costs can also represent a failure of recirculation when productive gains depend on ecological supports whose maintenance remains underfunded.

Definition 18.105 (Generative recirculation of AI surplus). *Generative recirculation of AI surplus* is the historically extended return of resources, access, time, knowledge, infrastructure, or other surplus-derived capacities into relational configurations that support the reproduction, diversification, repair, or expansion of future generative possibilities.

Generative recirculation can occur through market exchange, fiscal institutions, commons, households, organizations, philanthropy, public services, cooperative arrangements, or informal relations. The term identifies a functional role that can be performed through several policy and institutional instruments. The same institution can support some recirculation pathways while restricting others.

Proposition 18.106 (Recirculation feedback condition). *When AI-generated surplus is repeatedly recirculated into a narrow set of capability-controlling positions, the resulting feedback can reinforce concentration of productive intelligence. When recirculation sustains broader complementary capabilities, access, institutions, and alternatives, it can widen the relational base from which later generation occurs. The realized direction depends on the conversion mechanisms and governance structure of the recirculation pathway.*

Proposition 18.106 connects surplus analysis to the power and generativity framework of the book. A feedback loop centered on model ownership or infrastructure control can reproduce the conditions of later surplus capture. A broader loop can support public capability, commons, labor transition, care, knowledge, or participation. Mixed configurations are likely because the same surplus can be divided across several pathways.

The analysis of AI-generated surplus therefore yields a temporal sequence with several analytically distinct stages. Artificial productive capacity can create a productivity gain relative to a declared baseline. Ownership, bargaining, market structure, access, and institutional rules shape how the gain is realized and claimed. Concentrated returns can alter later capability and power. Redistribution can reassign realized claims. Generative allocation and social investment can convert current gains into future capacities. Recirculation determines which relational conditions receive renewed support across subsequent histories. These stages can overlap in practice, yet separating them prevents a productivity increase from being treated automatically as shared prosperity or a transfer from being treated automatically as structural transformation.

The next section examines redistribution more directly. Section 18.8 asks how income security, transfers, public services, access, capacity, participation, and meaning interact when material compensation is used to respond to AI-mediated changes in labor and surplus. The present section supplies the antecedent surplus architecture needed for that analysis.

18.8 Redistribution and Its Limits

This section develops the redistributive problem that follows when artificial productive capacity changes labor demand, ownership returns, and the realization of AI-generated surplus. Its role is to distinguish the economic objects that can be redistributed from the broader relational conditions through which people acquire security, access, capability, participation, and meaningful positions within an economic order. The objective is to identify what material redistribution can accomplish, which conversion mechanisms are required for redistributed resources to become effective capabilities, and which forms of exclusion or dependency remain when material claims have been improved. The discussion proceeds through income security, universal transfers, public services, distribution of access, distribution of capacity, participation, meaning, and the limits of material compensation. The method is relational and layered. Redistribution is treated as a family of interventions into historically structured claims, services, access relations, capability conditions, and participation

architectures rather than as a single scalar transfer from one income position to another.

The section builds directly on the surplus architecture in Section 18.7. AI-generated productivity gains can be realized through wages, profits, rents, lower prices, public revenue, time release, service expansion, and other heterogeneous returns. Redistribution reallocates some of those realized claims or the resources purchased through them, yet the economic consequences depend on the conversion pathways through which resources become security, access, capability, or participation. The distinction is especially important under artificial intelligence because employment can become a weaker route to income and social position while access to models, compute, institutions, verification, education, and decision processes becomes increasingly consequential. Korinek and Stiglitz analyze how AI-related technological change can affect income distribution and employment under different ownership and market arrangements (Korinek and Stiglitz 2019). The present analysis adds a relational question: which future possibilities are altered when redistribution changes material claims while other structures of productive intelligence remain concentrated?

A second antecedent comes from the capability and participation analyses developed earlier in the book. Sen's capability approach distinguishes possession of resources from the substantive opportunities that people can actually realize from them (Sen 1999; Sen 1992). Sections 18.4 and 18.5 similarly separated employment, income, contribution, recognition, participation, and subjective continuity. Redistribution can therefore be substantial without equalizing productive capability, relational standing, or meaningful participation. This section does not use that observation to discount material redistribution. Material security can be a major generative condition for learning, care, mobility, experimentation, exit, and participation. The analytical task is to state which layer a redistributive instrument addresses and which additional relations are required for its effects to travel further.

Definition 18.107 (AI-era redistributive architecture). An *AI-era redistributive architecture* is the historically situated configuration of transfers, public services, access arrangements, capability-supporting institutions, rights, and participation mechanisms through which claims on AI-mediated production and the conditions for using those claims are distributed across economic positions.

Definition 18.107 is broader than fiscal redistribution after market income has been realized. Tax-and-transfer institutions are one component. Public services, access rights, public or commons infrastructure, capability formation, and participation arrangements can alter effective distribution before, during, or after monetary income is assigned. The definition therefore allows several institutional sequences without treating them as interchangeable.

Table 18.8 supplies the organizing distinction for the section. Movement across the layers requires conversion rather than semantic substitution. Income can purchase some access; public services can provide some capabilities directly; capability can support participation; and secure participation can contribute to continuity and recognition. Each conversion can also fail. A transfer can encounter housing scarcity, inaccessible services, unavailable compute, weak verification capability, discriminatory institutional gates, or absence of consequential voice. The analysis therefore treats redistributive success as layer-specific before asking whether several layers

Table 18.8: Layers of redistribution under artificial intelligence. The layers distinguish reallocation of material claims from the conversion processes through which those claims can become access, capability, participation, or meaning-related conditions.

Layer	Primary redistributive object	Residual analytical question
Income security	Money income, replacement income, income floors, or insurance against large income interruption	Does material stability translate into viable access, capability, and alternatives?
Universal transfers	Broadly eligible monetary or in-kind claims supplied independently of a narrow employment relation	How do financing, prices, services, and ownership structure shape the real incidence of the transfer?
Public services	Shared or publicly provisioned health, education, care, housing, mobility, digital, cultural, or other service capacity	Are services practically accessible, adequate, maintainable, and responsive to heterogeneous needs?
Access distribution	Rights and practical routes to models, compute, networks, data, institutions, knowledge, and productive interfaces	Can formal access be converted into effective use without prohibitive complementary requirements?
Capacity distribution	Skills, time, health, verification ability, organizational support, infrastructure, and other conversion conditions	Do participants acquire durable capability or remain dependent on externally controlled capacity?
Participation	Standing and practical opportunity to contribute to knowledge, decisions, institutions, care, community, and culture	Does redistribution alter who can shape shared economic and institutional futures?
Meaning-related conditions	Recognition, reciprocal significance, role continuity, learning, care, and other conditions that can support meaningful participation	Which relational conditions require institutional or social reorganization beyond material compensation?
Material-compensation coverage	The set of losses, burdens, and constraints that material resources can substantially address in the declared context	Which power, relational, historical, or participation structures remain after compensation?

form a coherent architecture.

18.8.1 Income Security

Income security concerns the stability of material command over goods and services when labor income becomes volatile, intermittent, weakly connected to productivity, or unavailable. Artificial intelligence makes this object analytically important because Section 18.4 showed that task automation, employment scarcity, and wage-based distribution can diverge. A society can experience high productive capacity while some households face weak access to the monetary claims through which food, housing, mobility, care, communication, and other necessities are ordinarily obtained.

Income security has at least three dimensions. The first is *level*: the material claim available to a person or household over a declared period. The second is *volatility*:

the extent to which that claim can change unpredictably relative to recurrent obligations. The third is *continuity*: the availability of claims during transitions among employment, care, education, illness, retraining, relocation, or other life conditions. These dimensions matter separately. A comparatively high average income can coexist with destabilizing volatility, while a modest but reliable income floor can enlarge the practical capacity to refuse harmful terms, undertake training, provide care, or search for a better position.

Definition 18.108 (AI-transition income security). *AI-transition income security* is the historically situated capacity of an economic position to maintain a declared range of materially necessary and socially consequential activities across AI-mediated changes in employment, earnings, prices, or productive organization without requiring immediate acceptance of any available labor-market relation.

The definition treats income security as a capability-supporting condition rather than as a fixed currency amount. The relevant range of activities depends on prices, household structure, public services, debt obligations, care responsibilities, location, health, and other conversion conditions. A nominal transfer can therefore increase while real security remains unchanged when essential costs rise or required services become inaccessible.

Income security can also affect bargaining relations. A worker or household with a credible material fallback may have a wider feasible set of employment, training, relocation, entrepreneurial, or care options. In the language of the revised power framework in Chapter 16, a stronger fallback can alter the possibility structure through which another position exercises labor-market or contractual power. The effect remains context-dependent because alternative employment, legal rights, housing markets, social insurance, and household obligations also contribute to feasible exit.

Proposition 18.109 (Income-security option condition). *When additional income security enlarges the set of practically feasible alternatives available to an economic position during an AI-mediated transition, the redistribution can change bargaining and participation conditions in addition to increasing current consumption capacity. The magnitude and direction of that change depend on complementary institutional and material conditions.*

Proposition 18.109 makes income security generatively relevant. A transfer used only for immediate consumption can still be valuable. When it also preserves time, mobility, health, learning, care, or credible exit, it can change later relations. The distinction prevents current welfare and future generative capacity from being collapsed into one measure.

18.8.2 Universal Transfers

Universal transfers provide a particularly clear test of the distinction between material distribution and wider economic structure. For the present analysis, a universal transfer is defined by broad membership-based eligibility rather than by employment status, demonstrated productivity, or case-by-case proof of labor-market need. The transfer can be monetary or, where explicitly stated, an equivalent broadly available claim. This definition is analytical and does not prescribe one fiscal design, payment level, citizenship rule, or financing mechanism.

Universal eligibility can reduce the degree to which basic material claims depend on successful labor-market sorting. It can also reduce some administrative thresholds associated with narrowly targeted assistance and can give recipients greater discretion over heterogeneous needs. Those properties can become especially relevant when AI-mediated transitions create frequent movement among employment, training, care, informal contribution, and other forms of participation. A broad transfer can preserve continuity while the institutional classification of a person's productive role changes.

Definition 18.110 (Universal material claim). *A universal material claim is a broadly membership-based entitlement to a declared monetary or in-kind resource supplied independently of a recipient's current employment relation, task productivity, or contribution ranking within the covered population.*

Universality concerns the eligibility relation. The realized distributive effect depends on additional structures. Financing can alter disposable income at different positions. Housing, energy, health, or other bottlenecks can convert nominal purchasing power into price pressure or rents. Existing public services can be complemented or displaced depending on institutional design. Ownership structures determine where increased demand generates returns. Household relations can affect control over transferred resources. A common nominal transfer can therefore have heterogeneous real consequences.

Proposition 18.111 (Universal-transfer incidence condition). *The effective distribution produced by a universal material claim depends on the interaction among the transfer rule, its financing, the supply and pricing of essential goods and services, household and institutional control over resources, and the ownership structure through which additional expenditure becomes income elsewhere in the economy.*

Proposition 18.111 keeps the analysis relational. A universal transfer can strengthen income security while simultaneously increasing returns to concentrated housing, platform, or infrastructure ownership if supply and ownership conditions channel additional expenditure toward those positions. Conversely, broad transfers can support decentralized choice and participation when essential capacities and competitive alternatives are available. The proposition therefore treats the transfer as one relation within a larger allocation system rather than as a self-contained distributive outcome.

Universal transfers also leave open the question of productive intelligence. A person may have materially adequate income while lacking access to consequential models, compute, institutions, or decision channels. The following subsections therefore move from monetary claims to service, access, and capability structures.

18.8.3 Public Services

Public services redistribute through organized provisioning rather than through individual monetary claims alone. Education, health, care, mobility, housing support, legal assistance, libraries, digital connectivity, cultural infrastructure, and public computational or knowledge resources can each alter substantive opportunity when they are sufficiently accessible and adequate. A provisioning perspective is especially useful because some capabilities depend on maintained institutions, professional coor-

dination, shared infrastructure, or collective risk pooling that individual purchasing power does not reproduce automatically. Feminist economics has emphasized social provisioning as a foundational object of economic analysis, including the organization of care and household reproduction (Power 2004; Folbre 2001).

The redistributive object in public services is therefore partly infrastructural. A public clinic redistributes access to organized medical capability; a public school redistributes access to educational relations and institutional recognition; a library redistributes access to knowledge infrastructure; a public compute facility can redistribute access to productive intelligence. These arrangements can coexist with cash transfers, yet their conversion mechanisms differ. Services can pool expertise and infrastructure, coordinate standards, and reduce the need for each recipient to purchase a complete private substitute.

Definition 18.112 (Shared service provisioning). *Shared service provisioning* is an institutional arrangement through which a declared population receives practical access to maintained service capacity, infrastructure, expertise, or organized care under eligibility and governance rules that do not require each user to acquire the full underlying productive assets individually.

Shared provision can still be formally available and practically inaccessible. Distance, waiting time, language, disability, digital requirements, eligibility procedures, stigma, scheduling, quality differences, or institutional distrust can alter effective access. The existence of a nominal public entitlement therefore requires a second analysis of use conditions. This point mirrors the distinction between formal and effective access to productive intelligence in Section 18.6.

Proposition 18.113 (Cash–service non-equivalence). *A monetary transfer and a publicly or collectively provisioned service can produce overlapping material benefits while remaining non-equivalent redistributive instruments when the service depends on shared infrastructure, coordinated expertise, collective risk, institutional continuity, or access conditions that recipients cannot reproduce through an equal monetary claim alone.*

The proposition does not establish general priority of services over cash. Some needs are heterogeneous and can be better served by flexible individual command over resources. Some services can be poorly governed or unresponsive. The analytical implication is plural: redistribution can operate through claims and through shared capacity, and adequate institutional design depends on the object being distributed and the conversion structure of the population concerned.

18.8.4 Distribution of Access

AI-mediated production makes access itself a distributive object. Section 18.6 represented productive intelligence as a stack whose model, compute, data, platform, infrastructure, and rights layers can be owned or controlled separately. Redistribution can therefore target access to those layers even when asset ownership remains unchanged. Examples include access to public computational resources, subsidized connectivity, model interfaces, shared data facilities, libraries, laboratories, professional tools, legal permissions, or institutional gateways through which AI capability becomes economically usable.

Access distribution differs from income redistribution because some productive resources are difficult to purchase efficiently at the individual level or are governed by non-price restrictions. A person can possess sufficient money yet lack a license, data right, institutional credential, trusted identity, network membership, or compatible technical environment. Conversely, publicly supplied access can give a low-income user practical entry to high-value infrastructure that would be unaffordable as a privately owned asset.

Definition 18.114 (Distribution of productive-intelligence access). The *distribution of productive-intelligence access* is the relational pattern through which economic positions obtain practically usable routes to AI-relevant models, compute, data, platforms, networks, institutions, permissions, and complementary services under declared conditions of cost, continuity, portability, and contestability.

The definition emphasizes a bundle rather than a binary permission. Access that is temporary, revocable, non-portable, heavily monitored, technically constrained, or tied to a single platform can generate a different capability position from access with stable terms, interoperable tools, local adaptation rights, and credible alternatives. Redistributing nominal access while leaving these conditions unchanged can therefore produce weak equalization.

Proposition 18.115 (Access-redistribution conversion condition). *Redistribution of access enlarges effective productive opportunity when recipients possess or can obtain the complementary resources required to use the accessed system and when the access relation is sufficiently stable, intelligible, and operational for the relevant activity.*

This condition connects access redistribution to the complementarity analysis in Chapters 17 and 18. Model access can be ineffective without compute, data, verification, skills, organizational integration, or time. The next subsection therefore treats capability formation as a distinct redistributive layer.

18.8.5 Distribution of Capacity

The distribution of capacity concerns the practical ability to convert resources and access into sustained action. Sen's distinction between commodities, resources, and capabilities is relevant because equal resource bundles can yield different substantive opportunities under heterogeneous personal, social, and environmental conditions (Sen 1985; Sen 1992; Sen 1999). Under AI, conversion conditions can include technical literacy, domain expertise, verification ability, time, health, language, compute, organizational support, legal standing, trusted networks, and the ability to recover when a platform or tool changes.

Capacity redistribution can occur through education, apprenticeships, public technical support, accessible infrastructure, health and care systems, time security, organizational resources, shared professional services, or institutional reforms that remove conversion barriers. It can also involve preservation of capabilities that would otherwise atrophy under repeated delegation to AI. The object is therefore broader than reskilling for a currently demanded job. Capability determines which future tasks, institutions, and forms of participation remain available when the economic environment changes.

Definition 18.116 (Redistributed generative capacity). *Redistributed generative capacity* is an enlargement, produced through redistributive institutions or shared provision, of an economic position's durable ability to learn, verify, adapt, coordinate, create, care, deliberate, access productive systems, or otherwise participate in the generation of later possibilities.

The definition is intentionally plural. Capacity can be individual, collective, institutional, or infrastructural. A community laboratory, public-interest legal organization, cooperative data infrastructure, or municipal technical team can distribute capacity even when no single individual acquires all of the underlying expertise or assets. This is consistent with GRE's relational treatment of capability as partly located in maintained relations and organizations.

Proposition 18.117 (Resource–capacity conversion condition). *Redistributed resources become redistributed generative capacity when the relevant conversion chain supplies the complementary time, knowledge, infrastructure, institutional standing, health, coordination, and continuity needed for recipients to transform those resources into durable practical possibilities.*

Proposition 18.117 identifies a common source of apparent redistributive failure. A program can transfer resources correctly at the accounting level while producing little durable capability because one or more conversion links remain unavailable. The appropriate response depends on the missing link; the proposition does not imply that every problem should be addressed through additional monetary transfer.

Capacity redistribution also interacts with dependency. A person can become highly productive through continuous access to an externally controlled AI system while acquiring little independent capability to verify, contest, or continue when access is withdrawn. Such a configuration may increase realized output while deepening dependence. A GRE analysis therefore asks whether redistributed capacity includes viable alternatives and recovery pathways as well as immediate performance.

18.8.6 Participation

Participation concerns the ability to enter, sustain, and shape consequential relations within the economic system. Section 18.5 developed existential participation beyond employment, while Section 18.4 separated participation from labor-market demand. Redistribution matters to participation because material security, services, access, and capacity can remove barriers to involvement. Participation nevertheless has an additional relational dimension: a person can possess adequate income and capability while remaining outside institutions where decisions, knowledge, care, culture, or resource allocation are shaped.

Participation can take several forms. Productive participation concerns involvement in making goods, services, knowledge, or infrastructure. Institutional participation concerns standing in organizations and governance processes. Epistemic participation concerns contribution to inquiry, interpretation, verification, and collective knowledge. Care and community participation concern relational activities whose significance is not exhausted by market output. Cultural participation concerns creation, interpretation, and transmission of shared symbolic forms. The economic rel-

evance of these forms lies partly in their dependence on time, access, institutional design, and resource allocation.

Definition 18.118 (Participatory distribution). *Participatory distribution* is the distribution of practical standing, time, access, voice, capability, and institutional routes through which economic subjects can enter and influence consequential productive, epistemic, care, community, cultural, or governance processes.

Participatory distribution can be unequal even when income distribution is comparatively equal. Formal membership can also coexist with weak consequential participation when agendas, technical systems, credentials, information, meeting times, or decision rules exclude effective contribution. The object is therefore the practical structure through which participation becomes possible and consequential.

Proposition 18.119 (Material-support and participation non-equivalence). *Material redistribution can enlarge the conditions for participation by supplying time, security, mobility, services, and access. Consequential participation additionally depends on institutional standing, receptive interfaces, decision procedures, recognition, and opportunities for contribution. Improvement in material resources therefore does not by itself determine the distribution of participation.*

This proposition explains why redistribution and democratic or institutional reform can be complementary. A guaranteed income can give a person time to participate, while institutional rules determine whether that participation can shape outcomes. Public services can support participation by reducing care or health burdens, while inaccessible decision structures can continue to exclude. Distributional analysis therefore reaches into governance without reducing governance to income policy.

18.8.7 Meaning

Meaning requires especially careful scope because GRE is an economic research programme rather than a complete philosophical theory of the good life. The present subsection examines only the economic conditions that can support or undermine meaning-related participation. Earlier analysis in Section 18.5 showed that employment can bundle income, recognition, temporal structure, contribution, reciprocal dependence, learning, and social position. If AI weakens employment as the dominant institutional bundle, monetary redistribution can preserve material command while leaving some of those other relations to be reorganized separately.

Recognition theory helps identify one part of this problem. Honneth treats recognition relations as important to social freedom and the formation of practical self-relations (Honneth 1995). Arendt's distinctions among labor, work, and action likewise show that human activity and public appearance cannot be exhausted by an account of material production (Arendt 1958). GRE does not translate these theories directly into economic variables. It uses them to maintain analytical space for recognition, public participation, durable contribution, and relational continuity where an income-only model would be incomplete.

Definition 18.120 (Meaning-supporting economic conditions). *Meaning-supporting economic conditions* are material, temporal, relational, institutional, and participatory conditions that make sustained contribution, recognition, learning, care, inquiry,

creation, reciprocal significance, or other subjectively meaningful forms of economic participation practically available, without defining in advance which activities a particular subject will experience as meaningful.

The last clause is important. Institutions can secure time, access, rights, recognition pathways, spaces of contribution, and material safety. They cannot assign subjective meaning by administrative rule. A publicly funded art program can create access to practice and community; it cannot guarantee that a participant experiences artistic activity as meaningful. A care institution can support durable relations while failing to produce intimacy or trust. Economic policy can therefore shape the conditions of meaning without manufacturing meaning as an output.

Proposition 18.121 (Meaning-support non-equivalence). *Material security can remove constraints that obstruct meaningful participation and can support the time and stability required for care, learning, inquiry, creation, and public action. The subjective and relational significance of those activities depends on additional histories, relations, recognition structures, and forms of participation that are not reducible to the amount of material compensation supplied.*

The proposition does not diminish material conditions. Severe insecurity can foreclose activities before questions of recognition or meaning become practically accessible. The analytical ordering is therefore complementary: material sufficiency can be a prerequisite for wider participation while remaining incomplete as a description of the wider participatory architecture.

18.8.8 Limits of Material Compensation

The preceding layers permit a more precise account of the limits of material compensation. Some harms and losses are highly responsive to money or in-kind resources: lost earnings, transition costs, housing expenses, education fees, transport, care purchases, or temporary income interruption can often be addressed substantially through material provision when supply conditions are adequate. Other disruptions have structural or relational components that material compensation reaches only indirectly. Loss of access to a profession, disappearance of an institutional role, dependency on a controlled model, exclusion from decision processes, erosion of verification capability, loss of recognition, or foreclosure of future options can require changes in rights, infrastructure, governance, institutional design, or participation relations.

Definition 18.122 (Material-compensation coverage). *A material-compensation coverage profile identifies, for a declared AI-mediated disruption, which losses, burdens, constraints, and foreclosed possibilities can be substantially addressed through monetary or in-kind resources and which retained dimensions require additional access, capability, institutional, relational, governance, or historical repair.*

The coverage profile prevents two symmetric errors. One error is to assume that money can substitute for every lost relation or capability. The other is to treat material compensation as irrelevant whenever a loss also has relational dimensions. A displaced worker may need income security and a new participatory role. A community affected by infrastructure closure may need financial support and restoration of shared institutional capacity. A researcher excluded from a model ecosystem may

need funding and access rights. A person freed from labor-market necessity may benefit from income and from institutions through which learning, care, culture, and public contribution remain available.

Proposition 18.123 (Material-compensation adequacy condition). *Material compensation provides a comparatively complete response to an AI-mediated loss when the materially compensable dimensions constitute the relevant scope of the loss and when the supplied resources can be converted into the activities and alternatives at issue. Its coverage is partial when consequential residual dimensions lie in access, capability, rights, power, participation, recognition, institutional continuity, or historically structured future possibility.*

Proposition 18.123 makes the limit conditional rather than categorical. Many economic disruptions have mixed structure. Material compensation can be necessary and substantial while broader repair remains required. The relevant question is therefore which dimensions are present in the case under analysis and which institutional mechanism addresses each one.

The distinction also matters for AI-generated abundance. An economy could produce enough material output to finance broad income security while retaining highly concentrated productive intelligence, strong epistemic dependence, limited institutional voice, and narrow control over future capability. Conversely, broad public and commons access to productive systems could coexist with inadequate income security. Redistributive adequacy therefore has several dimensions whose joint organization cannot be inferred from aggregate output alone.

A generative-relational approach treats these dimensions as historically coupled. Income security can preserve time for learning; public services can convert income into health and education; access can expose people to productive systems; capability can make access usable; participation can shape how systems are governed; recognition and meaningful roles can support continued engagement; and those relations can influence the next allocation of AI-generated surplus. Feedback can also run in a concentrating direction when transfers flow back through rents, platform dependence, or infrastructure bottlenecks without changing the underlying access and power structure.

Proposition 18.124 (Redistributive layering condition). *An AI-era redistributive architecture is generatively broader when its material, service, access, capability, and participation layers are coordinated so that gains at one layer can be converted into viable possibilities at the next while preserving contestability and alternatives. Coordination does not require one institution to control every layer, and different layers can remain appropriately plural in governance and provision.*

The proposition summarizes the section without proposing a universal policy package. Different societies can combine transfers, services, commons, market institutions, public infrastructure, cooperative provision, rights, and participatory governance in different ways. GRE's contribution at this stage is diagnostic: it identifies the relational object addressed by each instrument and asks how that object changes later generative possibility.

Redistribution under artificial intelligence therefore has both substantial capacity and identifiable limits. It can stabilize material life, broaden access, finance services,

support capability formation, and enlarge feasible participation. It can also leave ownership, infrastructure control, epistemic authority, institutional standing, dependency, and meaning-related relations largely intact when those structures are outside the redistributive mechanism. The adequate unit of analysis is consequently a layered architecture rather than a single transfer variable.

Section 18.9 turns to the relational configurations through which humans and artificial systems participate together in economic activity. Complementarity, dependency, delegation, trust, verification, substitution, co-generation, collective organization, and co-evolution will be examined as relational dynamics whose distributional consequences depend on the material and participatory conditions established in the present section.

18.9 Human–AI Relational Economies

This section develops the relational configurations that arise when human subjects, organizations, and artificial systems participate jointly in economic activity. Its role is to move beyond comparisons of isolated capability and beyond ownership or redistribution considered separately. The objective is to identify how complementarity, dependency, delegation, trust, verification, substitution, co-generation, collective organization, and historical co-evolution alter the practical possibilities of the participating positions. The discussion treats artificial systems as economically consequential components of relational configurations without presuming human-equivalent subjecthood, consciousness, moral agency, or responsibility. The method is generative and relational: each configuration is analyzed through the operations it enables, the dependencies and interfaces it creates, the responsibilities and verification burdens it redistributes, and the way repeated coupling changes later capability and institutional structure.

The section builds on three antecedents. Section 18.2 established that human–AI capability differences are multidimensional and task-relative. Section 18.3 showed that such asymmetries become power-relevant only through identifiable mechanisms that deform the possibility structure of another position. Sections 18.4–18.8 then separated employment, contribution, participation, ownership, surplus, and redistribution. Human–AI relations can intersect all of these objects. A system can complement a worker while deepening platform dependence; assist a professional while redistributing verification burdens; substitute for selected tasks while leaving the wider social relation intact; or participate in a collective whose capability exceeds the capability of any isolated component. The relational form therefore cannot be inferred from model performance alone.

Empirical studies of generative AI in professional tasks already illustrate the importance of interaction effects. Experimental and field evidence has found productivity gains in selected writing and customer-support settings, while the magnitude and distribution of gains vary with task, worker position, and mode of use (Noy and Zhang 2023; Brynjolfsson et al. 2025). These findings support a bounded analytical point rather than a universal claim: the economic effect of AI depends partly on how the system is coupled to human activity. Research on algorithmic systems in organi-

zations similarly shows that control, evaluation, and work organization can be transformed through technical mediation rather than through automation alone (Kellogg et al. 2020). The present section generalizes this relational problem without treating any one observed arrangement as the inevitable form of human–AI economic order.

Definition 18.125 (Human–AI relational economy). A *human–AI relational economy* is a historically situated configuration in which human subjects, organizations, artificial systems, infrastructures, rules, and access arrangements are coupled through recurrent productive, epistemic, coordinative, care-related, cultural, or governance processes whose operation changes the capabilities, dependencies, claims, responsibilities, or future possibilities of at least some participating positions.

Definition 18.125 does not require one unified economy-wide architecture. Several relational economies can coexist within the same society: a professional service can use AI as an assistive tool, a platform can mediate large-scale delegation, a research group can organize hybrid inquiry, and a household can use artificial systems for planning or care-related support. The relevant unit is the maintained relational configuration through which capability becomes economically operative.

Table 18.9 supplies the organizing architecture. The dimensions can overlap, yet they should not be collapsed. Complementarity can exist with weak dependency, while dependency can persist after complementarity declines. Delegation can be narrow while trust is broad, or broad while verification remains strong. Co-generation can occur without a stable collective identity. Co-evolution is a historical property of the relational field rather than a synonym for any one moment of collaboration.

18.9.1 Complementarity

Complementarity concerns the additional capability generated when heterogeneous components can perform together operations that are unavailable, more costly, less reliable, or less generative when the components operate separately. In a human–AI configuration, complementarity can arise from differences in speed, memory, search, symbolic production, contextual understanding, embodied access, local knowledge, judgment, institutional standing, care, or responsibility. The relevant question is therefore relational: which capability of one position changes the practical use of a capability held by another?

A simple comparison of isolated performance can miss this structure. An artificial system with high symbolic-generation speed may have little economic value in a domain without human problem formulation, domain knowledge, verification, institutional authority, or integration into consequential workflows. A human expert can likewise become substantially more productive when the system reduces routine search, drafting, translation, coding, or comparison costs. Complementarity is present when the joint configuration alters the feasible operation set or the quality, cost, speed, robustness, or generativity of activity relative to declared separated configurations.

Definition 18.126 (Human–AI complementarity). A *human–AI complementarity* exists relative to a declared activity when coupling human and artificial capabilities generates a practically relevant operation, performance profile, resilience property, or future possibility that is unavailable or materially weaker under the comparison

Table 18.9: Relational dimensions of human-AI economic organization. The dimensions identify distinct forms of coupling and the analytical questions required before their economic consequences are inferred.

Dimension	Relational object	Principal analytical question
Complementarity	Joint configuration in which heterogeneous human and artificial capabilities enlarge feasible performance or possibility	Which capabilities are mutually enabling, and which complements remain scarce?
Dependency	Reliance on an AI-mediated relation for maintaining consequential activity or alternatives	What happens when access, quality, terms, or supporting infrastructure change?
Delegation	Transfer of selected operations, search, generation, filtering, or recommendation functions to an artificial system	Which authority, oversight, verification, and responsibility relations accompany the delegated operation?
Trust	Practical willingness to rely on AI-mediated outputs or operations under incomplete direct verification	Which evidence, institutional assurances, histories, or fallback mechanisms support warranted reliance?
Verification	Human, organizational, or machine-mediated processes used to assess outputs, provenance, constraints, and consequences	Who bears the verification burden, and is independent verification practically available?
Relational substitution	Replacement of a previously human-mediated operation or relation by an AI-mediated configuration	Which functions are substituted, which relational dimensions remain, and which new dependencies are created?
Co-generation	Production of an output, capability, relation, or later possibility through coupled human-AI operations	How are contribution, provenance, responsibility, learning, and benefit distributed across the generating configuration?
Human-AI collectives	Organized units whose practical capability depends on recurrent coordination among humans and artificial systems	Where are boundaries, decision rights, accountability, memory, and collective capability located?
Co-evolution	Historical feedback through which human practices, AI systems, institutions, and expectations mutually change	Which feedbacks stabilize, diversify, concentrate, or transform the relational field over time?

configurations in which the relevant capabilities are not jointly available.

The definition requires a comparison configuration because complementarity is not an intrinsic property of a technology. The same model can be complementary to one professional practice, substitutive for another operation, and largely irrelevant to a third. Organizational design can also alter the sign and magnitude of complementarity. A system that supports expert judgment under one workflow can constrain judgment when its outputs become mandatory or when performance metrics reward compliance rather than independent assessment.

Proposition 18.127 (Complementarity realization condition). *A potential human-AI complementarity becomes economically realized when the relational configuration supplies the interfaces, skills, time, verification, permissions, infrastructure, and organiza-*

tional integration required for the heterogeneous capabilities to be jointly usable in the consequential activity.

Proposition 18.127 explains why equal model access need not yield equal gains. Complementary resources differ across workers, firms, institutions, regions, and communities. Complementarity can therefore become a mechanism through which existing differences in expertise, infrastructure, or organizational capacity are amplified even when the underlying AI interface is broadly available.

Complementarity can also be endogenous. Repeated interaction can teach users how to formulate tasks, expose new domains of application, create specialized interfaces, and generate organizational routines. The joint capability of the configuration can consequently change through use. That historical process connects local complementarity to the co-evolution analysis at the end of the section.

18.9.2 Dependency

Dependency arises when continuation of an activity, role, capability, or institutional process becomes materially conditioned on maintenance of an AI-mediated relation. Section 18.3 treated dependency as one mechanism through which capability asymmetry can become power-relevant. The present subsection examines dependency as a relational-economic form even before a power conclusion is established.

Dependence is compatible with productive gain. A professional can become more capable through reliable AI assistance while simultaneously losing practical alternatives if workflows, clients, deadlines, or institutional expectations adapt around continuous availability of that assistance. An organization can lower costs through one model provider while making its data pipelines, evaluation routines, and employee skills difficult to transfer elsewhere. A community can benefit from shared AI infrastructure while becoming vulnerable to changes in funding or access conditions. Benefit and dependency therefore require separate descriptions.

Definition 18.128 (Human–AI dependency relation). *A human–AI dependency relation exists relative to a declared activity when the continuation, quality, feasibility, or recovery of that activity for a human or organizational position becomes materially conditioned on continued access to an artificial system or to the infrastructure, data, platform, or institutional relations through which that system is made operative.*

Dependency varies along several dimensions: substitutability, switching cost, reversibility, verification capacity, retained human skill, data portability, continuity of service, and availability of fallback processes. A high-performing arrangement with strong alternatives can create less dependency than a modestly useful system that becomes institutionally mandatory and difficult to exit.

Proposition 18.129 (Dependency persistence condition). *Human–AI dependency becomes more persistent when repeated use reorganizes skills, workflows, data, expectations, contractual relations, or infrastructure in ways that increase the cost of restoring or moving to alternative modes of activity.*

The proposition gives dependency a generative dimension. Dependence can be produced by the history of successful use rather than by an initial technical necessity. This path dependence also means that evaluating a current AI relation requires

attention to recovery pathways. Short-term productivity can coexist with long-term narrowing of alternatives.

Dependency does not by itself establish exploitation or unjust power. A mutually beneficial infrastructure relation can be highly dependent and well governed. The stronger evaluation depends on control, contestability, terms of access, risk allocation, benefit distribution, and the possibility of credible alternatives. Section 18.10 will examine the epistemic variant of this problem in greater depth.

18.9.3 Delegation

Delegation concerns the assignment of selected operations to an artificial system within a wider human or institutional activity. Delegated operations can include search, drafting, classification, scheduling, translation, prediction, recommendation, simulation, monitoring, coding, or the execution of bounded actions. Delegation becomes economically consequential when it changes the distribution of attention, time, expertise, authority, oversight, or responsibility within the relational configuration.

Delegation should be distinguished from disappearance of the human role. A physician can delegate document summarization while retaining diagnosis and responsibility; a researcher can delegate literature triage while retaining problem formation and evidential judgment; an organization can delegate scheduling while preserving human authority over allocation priorities. Conversely, an apparently narrow delegated operation can become structurally consequential when downstream decisions routinely follow its output.

Definition 18.130 (AI-mediated delegation). *AI-mediated delegation* is a relational arrangement in which a human or institutional position assigns a specified operation or class of operations to an artificial system while the surrounding configuration allocates the authority, oversight, verification, escalation, and responsibility associated with the delegated operation.

The surrounding allocation matters because execution and responsibility can diverge. A system can execute a recommendation process while a human retains formal responsibility, or an institution can retain legal responsibility while individual workers have little practical capacity to alter the system's operation. Delegation therefore requires analysis of both the delegated function and the governance of the delegation.

Proposition 18.131 (Delegation completeness condition). *A delegation arrangement is analytically specified only when the delegated operation, its operational boundaries, the conditions for human or institutional intervention, the verification pathway, and the location of residual responsibility are identified at the scale relevant to the inquiry.*

Proposition 18.131 prevents performance from standing in for governance. High task accuracy does not answer who can interrupt the process, who bears the consequence of failure, or how affected parties contest the output. Delegation can enlarge human capacity when routine operations are transferred while consequential judgment remains supported; it can also create responsibility gaps when execution, control, knowledge, and formal accountability become separated.

Repeated delegation can also transform the capabilities of the delegating position. Skills may atrophy, shift toward supervision, or develop in new directions. The resulting configuration therefore has to be studied historically rather than as a static division of labor.

18.9.4 Trust

Trust enters human–AI relational economies because direct verification of every system output or operation is often costly, delayed, or practically impossible. Economic activity therefore relies on forms of warranted or institutionally supported reliance. The analytical object is not an anthropomorphic belief that the machine possesses human character. It is the practical relation through which a user, organization, or affected party accepts exposure to an AI-mediated operation under incomplete direct verification.

Trust can be supported by several structures: observed reliability, domain validation, provenance, audit history, professional review, institutional guarantees, contractual remedies, monitoring, redundancy, reputation, certification, or the availability of fallback procedures. Different forms of trust can therefore attach to different parts of the system. A user can trust an institution’s governance while remaining uncertain about a particular model output, or trust a model within a narrow domain while distrusting the platform’s data practices.

Definition 18.132 (AI-mediated practical trust). *AI-mediated practical trust* is a context-specific willingness to rely on an artificial system or AI-mediated process for a consequential activity under incomplete direct verification, supported by a declared combination of observed performance, institutional assurance, provenance, monitoring, recourse, or other trust-bearing relations.

The definition treats trust as relational and scoped. It does not require person-like intentionality in the artificial system. It also distinguishes trust from unexamined acceptance. Reliance without identifiable support can occur, yet its epistemic or governance adequacy remains a separate question.

Proposition 18.133 (Trust calibration condition). *The practical adequacy of AI-mediated trust depends on correspondence between the scope of reliance and the evidence, monitoring, recourse, and verification capacities that support that reliance. Expansion of reliance beyond those supports increases the unresolved exposure carried by the relational configuration.*

Trust can lower transaction and coordination costs by reducing the need to verify every operation independently. It can also become a site of power when one party controls the evidence, standards, interfaces, or remedies through which trust is established. The next subsection isolates verification because trust and verification are complements rather than substitutes in many consequential settings.

18.9.5 Verification

Verification concerns the processes through which AI-mediated outputs, operations, provenance, constraints, and consequences are assessed against declared criteria. Verification can be performed by humans, institutions, independent technical sys-

tems, peer processes, or combinations of these. Its economic importance follows from scarcity: high-volume machine generation can reduce production costs while increasing the relative burden of checking, interpreting, and integrating outputs.

Verification in a relational economy has at least four objects. *Output verification* concerns the correctness or adequacy of a particular result. *Process verification* concerns the procedure through which the result was generated or selected. *Provenance verification* concerns data, source, version, and transformation history. *consequence verification* concerns downstream effects after the output enters an institutional or productive process. These objects can require different expertise and access rights.

Definition 18.134 (Human-AI verification architecture). A *human-AI verification architecture* is the organized distribution of criteria, evidence, expertise, access, review, monitoring, escalation, and recourse through which AI-mediated outputs and operations can be assessed before or after they become consequential.

The architecture can be asymmetric. A user may be required to verify an output without access to the data, model behavior, or institutional records needed to do so. A worker can bear responsibility for detecting errors while production quotas reduce the time available for checking. An organization can rely on a vendor's evaluation while lacking independent replication capacity. In such cases, the verification burden and verification capability are differently distributed.

Proposition 18.135 (Verification-burden alignment condition). A *human-AI relation* is more robustly verifiable when positions that bear consequential verification duties possess practical access to the evidence, time, expertise, tools, authority, and recourse required to discharge those duties at the relevant scale.

This proposition does not imply that every user must independently inspect model internals. Verification can be institutionally distributed. The requirement is that the overall configuration contain credible routes from consequential claims to appropriate verification and correction. Section 18.10 develops the deeper problem that arises when humans increasingly depend on AI systems for knowledge while lacking equivalent capacity to verify or interpret what those systems mediate.

18.9.6 Relational Substitution

Relational substitution occurs when an AI-mediated configuration replaces a relation or operation previously carried primarily through human participation. Task substitution is one special case. The broader relational question asks which functions of the earlier relation are reproduced, which disappear, which are transformed, and which new relations are introduced by the substitution.

A customer-service system can substitute for some conversational operations while changing escalation, recognition, accountability, and institutional access. An educational system can substitute for some explanation or practice generation while changing mentorship, peer relation, and the teacher's capacity to observe development. A care-support system can substitute for reminders, monitoring, or scheduling while leaving responsibility, reciprocity, embodied presence, and relational continuity elsewhere. The relevant unit is therefore the relation bundle rather than the task label.

Definition 18.136 (AI-mediated relational substitution). *AI-mediated relational substitution* is a historical change in which an artificial system or AI-mediated configuration assumes one or more functions previously carried through a human-mediated relation, thereby changing the composition, accessibility, responsibility, reciprocity, or continuity of the wider relation in which those functions were embedded.

The definition permits partial substitution. A relation can preserve some functions while changing others. It also permits substitution that improves access or continuity. An AI-mediated service can provide assistance where no human service was previously available, extend operating hours, or reduce routine burden. Such gains can coexist with losses in other relational dimensions.

Proposition 18.137 (Relational-substitution scope condition). *A claim of human replacement is analytically stronger than a claim of task substitution. The stronger claim requires specification of the relation being replaced and evidence that the consequential functions retained by the analysis have been transferred, removed, or made economically irrelevant under the new configuration.*

The proposition prevents a common scalarization of substitution. High performance on a bounded task can justify a task-level comparison while leaving the wider relational architecture underdetermined. Conversely, modest task substitution can have large relational consequences when the substituted task served as a gateway to recognition, learning, escalation, or institutional participation.

Relational substitution can therefore create new dependencies even when it removes older ones. Replacement of a human intermediary can reduce dependence on local availability while increasing dependence on platform access, model governance, or infrastructure continuity. Evaluation must follow the changed relational field rather than count only the number of automated tasks.

18.9.7 Co-Generation

Co-generation concerns outputs and possibilities produced through coupled human and artificial operations whose contribution structure cannot be represented adequately by assigning the entire result to one isolated component. Examples include iterative writing, software development, scientific exploration, design, simulation, translation, planning, and organizational problem solving. The concept is broader than simultaneous use: it requires that contributions interact in generating the resulting object or later possibility.

A human can supply the problem, constraints, evaluative judgment, domain interpretation, and selection among alternatives while an artificial system supplies candidate structures, transformations, retrieval, simulation, or rapid variation. The sequence can recur, with each output becoming input to the next operation. The resulting artifact can therefore carry a provenance that is relational and temporally extended.

Definition 18.138 (Human–AI co-generation). *Human–AI co-generation* is a generative process in which human and artificial operations are recurrently coupled so that the resulting artifact, decision support, capability, relation, or future possibility depends materially on contributions from more than one component of the coupled

configuration.

Co-generation does not by itself assign authorship, responsibility, ownership, or moral standing. Those are separate institutional and normative structures. A generated artifact can depend causally on an AI system while legal authorship remains human or institutionally defined; responsibility for its use can remain with a human professional; model and infrastructure owners can hold separate contractual rights. Contribution therefore has to be traced without presuming that every form of contribution receives the same status.

Proposition 18.139 (Co-generation provenance condition). *Analysis of human–AI co-generation is more informative when it preserves the sequence and type of contributions sufficiently to distinguish problem formation, source provision, transformation, candidate generation, evaluation, selection, verification, integration, and consequential use where those distinctions matter to the inquiry.*

The proposition connects co-generation to Chapter 17’s preservation and provenance architecture. Provenance supports responsibility, learning, error localization, attribution, and later re-epistemization. It also prevents the entire process from being summarized by the final artifact alone.

Co-generation can enlarge human capability or externalize it. A user who learns through iterative interaction can retain new capability after the system is removed; another can become dependent on the system for operations previously performed independently. The economic evaluation therefore includes both the co-generated output and the capability trajectory of the participating positions.

18.9.8 Human–AI Collectives

Repeated complementarity, delegation, verification, and co-generation can stabilize into organized collective forms. A human–AI collective can include individuals, teams, artificial systems, databases, workflows, institutions, and infrastructures whose coordinated operation produces a capability that belongs to the configuration as a whole rather than to any single component. The analytical challenge is to identify the collective boundary without turning every technology-using organization into one undifferentiated hybrid subject.

Situated-learning and community-of-practice traditions emphasize that capability can be distributed across participation, practice, and social organization rather than residing solely inside isolated individuals (Lave and Wenger 1991; Wenger 1998). Human–AI collectives extend the economic question because artificial systems can become recurrent components of the practice architecture. The present analysis uses this point structurally; it does not infer that artificial components participate socially in the same manner as human members.

Definition 18.140 (Human–AI economic collective). *A human–AI economic collective is an organized relational configuration whose sustained productive, epistemic, coordinative, care-related, cultural, or governance capability depends on recurrently integrated human and artificial operations, together with maintained rules, infrastructures, memory, and decision interfaces that make the joint capability reproducible across more than one isolated interaction.*

The collective has several analytically separable properties: boundary, membership or component criteria, decision rights, shared or distributed memory, workflow, verification structure, accountability, resource claims, and continuity conditions. These properties need not be concentrated in one legal organization. A research network, open-source project, public service, or supply chain can display collective capability across organizational boundaries.

Proposition 18.141 (Collective-capability non-reducibility condition). *Where recurrent coordination among human and artificial components generates capabilities that depend on the maintained relations among those components, analysis of the collective cannot be replaced by an inventory of isolated component capabilities without losing information about coordination, memory, verification, sequencing, and institutional support.*

The proposition does not claim that the collective is a unitary subject. Collective capability and collective subjecthood are distinct questions. Responsibility can remain legally or institutionally distributed even when capability is relationally collective. This distinction will matter later when the chapter examines heterogeneous subjects and value structures.

Human–AI collectives can also alter competition and inequality. Organizations with superior routines for integrating similar models can outperform organizations that possess comparable model access. Collective capability can therefore become a durable complementary asset. The distribution of such relational capability depends on training, organizational memory, infrastructure, governance, and the capacity to preserve and revise successful practices.

18.9.9 Co-Evolution of Human–AI Relational Fields

Human–AI relations change through repeated interaction. Users adapt tasks to systems; organizations redesign workflows; model developers respond to observed use; institutions create standards and liability arrangements; workers acquire or lose skills; markets alter expectations; and new forms of access, dependence, trust, and substitution become normalized. The object is therefore a relational field whose participants and interfaces co-evolve rather than a fixed technology inserted into an otherwise unchanged economy.

Co-evolution can occur through several feedback routes. Complementarity can encourage investment in specialized human skills and interfaces. Dependency can encourage platform-specific routines that raise switching costs. Delegation can relocate expertise toward supervision or reduce opportunities for practice. Verification failures can generate standards, audits, or human review institutions. Successful co-generation can produce new organizational forms. Relational substitution can reduce one human interaction while increasing demand for another, such as escalation, care, governance, or interpretation. These changes alter the environment in which the next generation of systems is designed and adopted.

Definition 18.142 (Human–AI relational-field co-evolution). *Human–AI relational-field co-evolution* is the historically extended process through which recurrent coupling among human practices, artificial systems, institutions, infrastructures, norms, and economic incentives changes the capabilities, expectations, dependency

structures, interaction rules, and future development conditions of more than one component of the relational field.

The definition does not require biological analogy or symmetric adaptation. One component can change much faster than another, and institutional rules can lag behind technical capability. Co-evolution here denotes reciprocal historical conditioning of the field, not equal causal influence among its components.

Proposition 18.143 (Relational-field path-dependence condition). *When repeated human-AI coupling modifies skills, infrastructures, data, organizational routines, standards, expectations, or access relations that subsequently affect which forms of coupling are feasible, the later relational field becomes path-dependent on the history of earlier human-AI organization.*

This condition links Chapter 18 to the generative-spacetime analysis of Chapter 15. Early institutional choices can shape later alternatives even when the underlying models improve substantially. A proprietary workflow can create switching costs; a public or commons infrastructure can preserve plural experimentation; a verification norm can maintain human capability; a labor arrangement can encourage augmentation or substitution. These histories become part of the capability landscape within which later AI systems operate.

Co-evolution can also modify the categories through which human and artificial contribution are understood. A task initially described as uniquely human can become routine after technical change; another can acquire greater significance because AI abundance makes human judgment, care, presence, or accountability relatively scarce. Such category changes can themselves affect investment, education, prestige, wages, regulation, and subjective orientation. The relational field therefore contains both material and symbolic feedback.

Proposition 18.144 (Plural relational-development condition). *The existence of strong technical capability does not uniquely determine one human-AI relational economy. Different institutional arrangements can organize similar capabilities through different combinations of complementarity, dependency, delegation, verification, substitution, collective participation, and access, thereby generating different later capability and power structures.*

Proposition 18.144 preserves institutional contingency. Technical capability constrains and enables possible arrangements, yet governance, ownership, public infrastructure, professional norms, labor institutions, education, and community practices influence which relational configurations become persistent. The long-run question is therefore not only which systems become technically possible but which human-AI relational fields societies reproduce.

The section has treated human-AI economic relations as historically developing configurations rather than isolated acts of tool use. Complementarity can generate new joint capability; dependency can narrow alternatives; delegation reallocates operations and oversight; trust makes action possible under incomplete verification; verification distributes epistemic burdens; substitution reorganizes relation bundles; co-generation produces relationally constituted outputs; collectives stabilize joint capability; and co-evolution changes the field in which later interactions occur. None of these relations alone determines whether an arrangement is desirable, exploitative,

empowering, or just. Those evaluations require the relevant power, distributional, epistemic, participatory, and normative structures to be specified.

Section 18.10 narrows the analysis to one especially consequential configuration: epistemic dependence on artificial intelligence. Machine-mediated knowledge can become central to economic participation while verification, interpretation, audit, contestability, and preservation of human epistemic agency remain unevenly distributed. The next section therefore examines those epistemic dependencies directly rather than treating them as an undifferentiated consequence of the broader human–AI relational field.

18.10 Epistemic Dependence on AI

This section develops epistemic dependence on artificial intelligence as a distinct economic relation within the wider human–AI relational field. Its role is to identify how recurrent reliance on AI systems can reorganize the practical capacity to acquire, interpret, verify, contest, preserve, and independently regenerate knowledge. The objective is narrower than a general theory of machine-mediated knowledge and stronger than a description of ordinary tool use. Chapter 5 examined the warrant, representation, and contestability of machine-mediated relational knowledge, while Section 17.16 identified AI-mediated epistemic dependence as an interface between the epistemic economy and wider capability asymmetry. The present section asks what happens when such dependence becomes embedded in consequential work, learning, research, administration, and decision processes. The discussion proceeds through machine-mediated knowledge, verification gaps, interpretive dependence, model opacity, infrastructure dependence, contestability, audit, and preservation of human epistemic agency. The method is relational and historical: dependence is evaluated through substitution, verification, reconstruction, challenge, continuity, and the later capability effects produced by repeated use.

Epistemic dependence is compatible with productive specialization. Complex societies rely on laboratories, libraries, expert professions, software, measurement systems, databases, and institutions that no individual can reproduce independently. AI extends this division of epistemic labor by making search, synthesis, translation, classification, coding, prediction, and symbolic generation available at new scales. The analytical problem therefore concerns the architecture of dependence rather than dependence in the abstract. A reliance relation can be robust where verification, plural expertise, portability, institutional memory, contestability, and fallback capacity remain available. The same relation can become fragile where consequential epistemic functions are concentrated in systems whose outputs are difficult to check, whose internal changes are weakly observable, whose infrastructure is externally controlled, and whose use displaces the human capabilities required for independent reconstruction.

Definition 18.145 (AI-mediated epistemic dependence architecture). *An AI-mediated epistemic dependence architecture is the historically maintained configuration of artificial systems, human capabilities, organizations, infrastructures, verification arrangements, records, access rights, and fallback relations through which an econom-*

Table 18.10: Dimensions of AI-mediated epistemic dependence. The dimensions distinguish the epistemic function being delegated or mediated from the conditions required for continued human and institutional capacity.

Dimension	Dependence object	Principal analytical question
Machine-mediated knowledge	AI-mediated retrieval, synthesis, generation, classification, or inference embedded in consequential practice	Which parts of the epistemic pathway remain independently reconstructible?
Verification gap	Difference between capacity to generate or receive outputs and capacity to test their standing	Who can check what, at what cost, with which evidence and tools?
Interpretive dependence	Reliance on AI-mediated framing, summarization, ranking, or explanation for making material intelligible	Which interpretive alternatives and contextual capacities remain available?
Model opacity	Limits on access to or intelligibility of system construction, behavior, failure conditions, or updates	Which opacity source matters for the consequence under study, and what compensating evidence exists?
Infrastructure dependence	Reliance on externally controlled models, compute, retrieval, data pipelines, or service interfaces	What happens to epistemic continuity when access, terms, architecture, or provider behavior changes?
Contestability	Practical capacity to challenge claims, categories, outputs, procedures, or uses	Can affected positions introduce counter-evidence and obtain consequential review?
Audit	Organized reconstruction and testing of system behavior, provenance, controls, and institutional use	Is audit independent, adequately scoped, and connected to authority for correction?
Human epistemic agency	Maintained capacity of human or human-governed institutions to orient, judge, verify, revise, and continue inquiry	Does recurrent AI use enlarge, preserve, externalize, or erode the capabilities needed for later independent epistemic action?

ically consequential epistemic function depends materially on AI-mediated operations and through which the consequences of failure, change, challenge, or withdrawal are distributed among participating positions.

Definition 18.145 treats dependence as a configuration rather than as a binary attribute. Two organizations can use the same model while occupying very different dependence positions because one retains domain expertise, local records, multiple providers, internal verification, and reconstructible workflows while the other has allowed the model-mediated pathway to become its only practical route to the relevant function.

Table 18.10 organizes the section around a central distinction: current epistemic performance and retained epistemic agency can move differently. An AI-mediated configuration can raise immediate accuracy, speed, breadth, or accessibility while simultaneously weakening some internal capacity for verification or reconstruction. Another configuration can improve both current performance and later human capability by making evidence, critique, explanation, and deliberate practice more avail-

able. The long-run economic significance therefore depends partly on the capability trajectory generated by the relation.

18.10.1 Machine-Mediated Knowledge

Machine-mediated knowledge concerns epistemic activity in which artificial systems become recurrent intermediaries between an epistemic target and the human or organizational position that acts upon it. The system may retrieve sources, summarize records, translate languages, generate explanations, synthesize alternatives, classify cases, produce code, infer patterns, recommend evidence, or construct candidate answers. The economic importance of these operations lies in the way they can become part of ordinary capability: a worker, researcher, student, administrator, or institution may become able to perform an epistemic function only because the AI-mediated pathway is practically available.

The present subsection builds on the machine-mediated relational-knowledge analysis of Chapter 5 while changing the object of inquiry. Chapter 5 asks how machine-mediated claims are warranted. Here the question is whether repeated mediation changes the dependency structure of the knower. A system can remain a replaceable convenience, become a high-value complement, or become an epistemic bottleneck whose withdrawal materially reduces the user's practical ability to continue the function.

Definition 18.146 (AI-mediated epistemic function). *An AI-mediated epistemic function is a recurring economically consequential activity of retrieval, interpretation, classification, inference, generation, verification, orientation, or communication whose practical execution materially incorporates an artificial system into the pathway connecting evidence, representation, judgment, and action.*

The definition does not assign the system independent epistemic authority. The same function can remain governed by human professionals, organizations, public institutions, or collective procedures. What changes is the structure of execution. The system becomes part of the pathway through which the epistemic object becomes accessible and usable.

Repeated mediation can generate cumulative efficiencies. Prompt libraries, retrieval indexes, organization-specific context, templates, evaluation routines, and user skill can make the relation more productive over time. These same investments can increase switching costs. A team that reorganizes its documentation, workflow, or internal language around one AI interface may become more productive while also making later substitution more expensive. Dependence can therefore arise through successful complementarity rather than through technical failure.

Proposition 18.147 (Epistemic mediation persistence condition). *When an AI-mediated epistemic function becomes embedded in recurrent workflows, records, skills, interfaces, or institutional expectations that are costly to reconstruct through an alternative pathway, the epistemic relation acquires a persistence mechanism beyond the immediate usefulness of the model output itself.*

Proposition 18.147 directs attention to organizational history. Dependence can persist even after technically comparable alternatives appear because documents,

habits, data schemas, evaluation routines, or institutional approvals were built around an earlier system. This historical layer connects epistemic dependence to the path-dependence analysis developed throughout the book.

18.10.2 Verification Gap

A verification gap appears when the practical capacity to obtain or generate an output exceeds the practical capacity to evaluate whether that output deserves reliance for its intended use. Artificial systems can widen this gap because high-quality surface form, rapid generation, and broad domain coverage can make production inexpensive while domain-specific checking remains costly. Section 17.7 treated verification asymmetry as one component of the epistemic economy. The present problem is the dependence relation created when the same position that benefits from expanded generation cannot independently verify the resulting epistemic material at a comparable scale or within the relevant decision horizon.

Verification costs differ by domain. Checking a translation can require fluency; checking generated code can require execution, testing, security review, and dependency inspection; checking a legal or scientific synthesis can require source access and domain expertise; checking a statistical claim can require data, computation, and methodological competence. AI can reduce some of these costs through cross-checking, testing, retrieval, or automated comparison, yet verification performed by the same model family can leave common-mode failure, shared training limitations, or correlated blind spots unresolved.

Definition 18.148 (AI verification gap). An *AI verification gap* exists for an epistemic function when the capacity to generate, receive, or operationally use AI-mediated outputs materially exceeds the capacity of the relevant position or its accessible institutions to test the outputs' provenance, validity, limitations, consistency, or consequences to the degree appropriate for the decision at stake.

The gap is relational rather than absolute. A user can have little direct verification capability while being embedded in a strong institutional architecture of peer review, professional oversight, certified testing, or independent audit. Conversely, a technically skilled user can face a large verification gap when required data or model behavior remain inaccessible.

Proposition 18.149 (Verification-burden relocation). *When AI lowers the marginal cost of candidate epistemic production more rapidly than it lowers the cost of consequential checking, part of the economic burden of the epistemic pathway shifts from production toward verification, selection, provenance, integration, and responsibility.*

The proposition is conditional and does not imply that AI inevitably increases total verification cost. The relevant issue is the relative capacity of the whole pathway. Where verification infrastructure scales effectively with generation, dependence can remain manageable. Where generation scales while checking remains bottlenecked, organizations can respond by narrowing review, relying more heavily on provider reputation, accepting higher residual uncertainty, or limiting the contexts in which AI-mediated outputs are permitted to act.

Verification gaps can also reshape expertise. If routine generation is externalized

while humans increasingly specialize in evaluation, the value of domain judgment can rise. If organizational incentives reward throughput without allocating time for checking, verification expertise can atrophy despite becoming more important. Economic analysis should therefore examine both the formal availability of verification and the institutional conditions under which it can actually be exercised.

18.10.3 Interpretive Dependence

Interpretive dependence arises when an artificial system becomes a recurrent intermediary in deciding how information is framed, summarized, categorized, prioritized, explained, or connected to possible action. The dependence can occur even when the underlying sources remain formally accessible. A person may possess the original document yet rely on an AI-generated summary to determine what matters; an organization may possess raw data yet rely on a model-generated classification to make the data intelligible; a researcher may possess a literature corpus yet rely on AI-mediated synthesis to construct the field's apparent structure.

Interpretive mediation can be highly valuable. It can reduce linguistic barriers, expose alternative formulations, reorganize complex material, or help novices enter unfamiliar domains. The dependence issue begins when interpretive alternatives become difficult to generate, compare, or sustain without the system. Longino's account of social knowledge emphasizes the epistemic importance of critical interaction among perspectives and background assumptions (Longino 1990). AI-mediated interpretation can widen that interaction when it surfaces neglected perspectives, while it can narrow it when repeated use standardizes framing or when ranking systems make a small set of interpretations disproportionately visible.

Definition 18.150 (AI-mediated interpretive dependence). *AI-mediated interpretive dependence* is a condition in which a position's practical ability to render consequential information intelligible, salient, comparable, or actionable relies materially on AI-mediated framing or synthesis and the position lacks readily available alternative interpretive pathways of sufficient quality within the relevant horizon.

Interpretive dependence should be distinguished from simple use of explanation. A learner can rely on an AI explanation while simultaneously developing stronger independent interpretive capability. Dependence becomes structurally important where the system carries the framing operation externally and later human capacity to generate, compare, or contest interpretations remains weak.

Proposition 18.151 (Interpretive plurality condition). *AI-mediated interpretation is less dependence-inducing, other conditions held fixed, when users retain practical access to source material, alternative framings, domain expertise, disagreement, and procedures through which the relevance or meaning assigned by the system can be revised.*

Proposition 18.151 concerns architecture rather than a guarantee of truth. Multiple interpretations can all be inadequate. The condition preserves the capacity for interpretive revision and reduces the likelihood that one model-mediated framing becomes the only practically available route through which the epistemic object can be understood.

18.10.4 Model Opacity

Opacity can deepen dependence because users may rely on a system whose behavior cannot be fully reconstructed from the information available to them. Burrell distinguishes opacity arising from intentional secrecy, technical literacy, and the scale or complexity of machine-learning systems (Burrell 2016). These sources require different economic and institutional responses. Contractual secrecy concerns access rights and disclosure. Technical opacity can sometimes be reduced through expertise, tools, documentation, or education. Complexity-related opacity can remain even where code or parameters are formally available because the system's behavior is difficult to anticipate, summarize, or trace exhaustively.

The relevant question is consequence-specific. Complete internal transparency is unnecessary for many low-stakes uses, while consequential reliance can require stronger evidence about training conditions, evaluation, failure modes, update procedures, security, data provenance, or operational controls. Opacity should therefore be analyzed against the epistemic function and the type of dependence it creates rather than treated as one uniform defect.

Definition 18.152 (Consequence-relative model opacity). *Consequence-relative model opacity* is the shortfall between the information and understanding practically available about an AI system's construction, behavior, limitations, or change history and the information required to evaluate, govern, or contest the system adequately for a specified consequential epistemic use.

This definition separates opacity from complexity alone. A complex system can be sufficiently governable for one use when external validation, monitoring, documentation, and fallback procedures are strong. A simpler system can remain consequentially opaque where its categories, data, or update rules are hidden from affected positions.

Documentation can reduce some forms of opacity. Dataset documentation, for example, can record motivation, composition, collection, preprocessing, and recommended uses (Geburu et al. 2021). Accountability architectures can also verify compliance with declared properties without requiring every affected person to inspect the full internal system (Kroll et al. 2017). These arrangements relocate epistemic work toward institutions capable of testing and certifying relevant properties.

Proposition 18.153 (Opacity-compensation condition). *Where direct intelligibility of an AI system remains limited, epistemic dependence can be governed more robustly when independent testing, documentation, provenance, monitoring, version history, constrained use, and consequential review provide evidence adequate to the risks of the declared function.*

The proposition does not equate external audit with full explanation. It states that epistemic adequacy can be supported by several complementary mechanisms when exhaustive internal understanding is unavailable or inefficient.

18.10.5 Infrastructure Dependence

Epistemic reliance can be deep even when the model itself is replaceable. AI-mediated knowledge frequently depends on a stack of model hosting, compute,

retrieval systems, data stores, identity services, application interfaces, networking, logging, proprietary connectors, and organizational integrations. Section 18.6 treated these layers as distinct ownership and control sites. The epistemic question is what happens to inquiry or decision capability when one of these supporting layers changes.

Infrastructure dependence can appear through several mechanisms. A provider can discontinue a model version on which an organization's evaluation history depends. Pricing changes can make repeated verification or large-scale retrieval uneconomic. Interface changes can break local tools. A proprietary embedding or retrieval system can make records difficult to migrate. Cloud or identity dependencies can block access to otherwise portable models. Internal expertise can be organized around one vendor environment. The epistemic object is therefore the continuity of the knowledge function, not merely uptime of the service.

Definition 18.154 (AI epistemic infrastructure dependence). *AI epistemic infrastructure dependence* is a condition in which continued performance, reconstruction, or verification of an economically consequential epistemic function materially relies on one or more externally controlled technical or organizational supports whose loss, alteration, or restriction cannot be absorbed through available substitutes within the relevant horizon.

Dependence can be reduced without full self-provision. Portability, interoperability, exportable records, versioned prompts and workflows, open standards, local fallback models, contractual continuity, public infrastructure, or multi-provider architectures can each preserve alternatives. The appropriate mechanism depends on the consequence and the cost of redundancy.

Proposition 18.155 (Epistemic continuity condition). *For AI-mediated functions whose interruption would materially reduce institutional or human epistemic capability, robust continuity requires preservation of enough data, provenance, workflow specification, access rights, human expertise, and substitutable infrastructure to reconstruct an adequate pathway after plausible changes in provider, model, interface, or service availability.*

The proposition links infrastructure dependence to preservation and later reconstruction. Continuity requires more than backups of final outputs. Reconstructing the epistemic pathway can require source records, model versions, retrieval indexes, prompts, evaluation criteria, decision logs, and human knowledge capable of interpreting those artifacts.

18.10.6 Contestability

Contestability concerns the practical capacity to challenge an AI-mediated epistemic claim or its consequential use. Chapter 5 developed contestability across data, categories, models, decisions, and historical records. In the present section, the focus is dependence: whether a position that relies on AI retains credible routes to question the system without losing the capability or standing that the system mediates.

A challenge can target several objects. A user may dispute factual content, provenance, or interpretation. An affected person may challenge a classification or the

relevance of the category applied. An organization may contest a provider's evaluation claim. A professional may seek to override an automated recommendation. A public institution may need to challenge a vendor's assumptions while remaining operationally dependent on the vendor's infrastructure. Contestability is strongest when the system's user, affected subjects, independent reviewers, and governing institution each have appropriately scoped routes for challenge.

Definition 18.156 (AI epistemic contestability). *AI epistemic contestability* is the practical capacity of relevant positions to identify a consequential AI-mediated epistemic claim or process, introduce qualified counter-evidence or alternative interpretation, obtain review by an actor or procedure with sufficient independence and authority, and preserve the resulting correction, disagreement, or limitation for later use.

The definition makes authority part of contestability. A complaint channel that cannot alter a consequential output or its later use provides expressive voice but weak corrective capacity. Conversely, a technically sophisticated audit can have limited contestability value if the findings cannot reach decision makers or affected positions.

Proposition 18.157 (Dependence-compatible contestability). *Meaningful contestability under AI-mediated dependence does not require elimination of specialized or proprietary systems; it requires sufficiently independent evidential access, review capacity, correction authority, and preserved records that consequential claims can be challenged without the challenged system controlling the entire challenge pathway.*

This proposition is compatible with differentiated disclosure. Privacy, security, intellectual property, or misuse concerns can justify controlled access. Independent review, secure testing environments, trusted intermediaries, or representative challenge can provide contestability where universal disclosure would be inappropriate.

18.10.7 Audit

Audit is one institutional response to epistemic dependence. Its role is to reconstruct and test selected properties of the AI-mediated pathway through procedures that are more systematic and independent than ordinary user reliance. Audit can examine data provenance, access controls, model evaluations, update histories, logging, monitoring, security, error patterns, documentation, organizational procedures, or compliance with declared standards. Kroll and colleagues emphasize that accountable algorithmic systems require mechanisms capable of verifying properties and compliance rather than relying solely on informal trust (Kroll et al. 2017).

Audit should be separated from explanation and from certification. Explanation concerns intelligibility of a particular output or process. Audit examines a declared system, period, or control environment against specified criteria. Certification can communicate that an external standard has been met. The three can interact while performing different epistemic roles.

Definition 18.158 (AI epistemic audit). *An AI epistemic audit* is a bounded and reconstructible procedure through which an appropriately positioned reviewer evaluates declared epistemic properties, risks, controls, or historical records of an AI-mediated function using specified evidence, criteria, scope, and reporting rules.

Audit quality depends on access, independence, competence, scope, timing, and

consequences. An auditor who cannot inspect relevant logs or data may verify only surface behavior. A technically capable auditor dependent on the auditee for continued business can face independence constraints. A comprehensive report that arrives after an irreversible decision can have little corrective value. A strong audit can still miss unanticipated failure modes because its criteria define what is inspected.

Proposition 18.159 (Audit-effectiveness condition). *AI audit reduces epistemic dependence most effectively when the audit has access to evidence material to the declared risk, sufficient technical and domain competence, practical independence from the object audited, temporal relevance to consequential decisions, and an institutional route through which findings can trigger correction, restriction, compensation, redesign, or further review.*

Audit also produces records that can support future re-epistemization. Preserved versions, evaluation datasets, incident logs, challenge histories, and audit findings make it possible to reconstruct how a system behaved and how an institution responded. Where these records disappear with a vendor or model update, later scrutiny can become impossible even when the original deployment was heavily audited at the time.

18.10.8 Preservation of Human Epistemic Agency

The deepest economic issue in sustained epistemic dependence concerns what capability remains with human subjects and human-governed institutions after AI mediation becomes ordinary. Human epistemic agency is used here in a bounded practical sense. It concerns the capacity to formulate questions, seek evidence, interpret, judge, verify, contest, revise, explain, preserve records, and continue inquiry through socially organized human institutions. The term does not require isolated self-sufficiency. Human agency is relational and has always depended on language, education, instruments, archives, expert communities, and infrastructures.

AI can enlarge this agency. Translation can widen access; adaptive explanation can lower entry barriers; search and synthesis can expand the field a person can inspect; coding assistance can enable experimentation; simulation can improve counterfactual reasoning; and critique can expose omissions. The same systems can externalize capabilities when users cease to practice or institutions cease to maintain the expertise required to understand and challenge consequential outputs. The relevant question is the direction of capability formation under repeated use.

Definition 18.160 (Human epistemic agency preservation). *Human epistemic agency preservation* is the maintenance or enlargement, across repeated AI-mediated activity, of the practical human and human-governed institutional capacities required to orient inquiry, access relevant evidence, generate and compare interpretations, verify consequential claims, contest epistemic authority, reconstruct material processes, and continue the epistemic function under plausible changes in AI support.

This definition treats agency preservation as multidimensional. A system can improve problem formulation while weakening independent calculation; improve access while weakening source-reading habits; improve organizational throughput while reducing internal model-evaluation expertise. Evaluation should therefore use a capability profile rather than one binary judgment that AI either augments or

deskills its users.

Proposition 18.161 (Epistemic agency retention condition). *An AI-mediated epistemic arrangement better preserves human epistemic agency when recurrent use maintains practical opportunities for source access, independent judgment, verification, disagreement, deliberate practice, reconstruction, and fallback action at the levels required by the consequences of the function.*

The condition does not imply that humans should duplicate every machine operation. Complete duplication can be inefficient or impossible. The relevant preservation target is capability sufficient for orientation, governance, challenge, recovery, and continued participation. A laboratory need not reproduce a semiconductor fabrication chain to preserve scientific agency, yet it may need enough understanding, calibration capacity, independent standards, and alternative evidence to detect when an instrument or service is misleading. AI-mediated systems require an analogous distinction between productive specialization and disabling dependence.

Education and organizational design become especially important. If AI performs every intermediate step invisibly, learners can achieve outputs without encountering the judgments through which expertise develops. If systems expose sources, invite prediction before assistance, support critique, preserve revision histories, and allocate responsibility for checking, the same technology can participate in capability formation. The economic value of AI should therefore include its effect on the future stock and distribution of human epistemic capability, not only its effect on present output.

Proposition 18.162 (Epistemic-agency externalization risk). *Where a consequential epistemic function is repeatedly performed through AI while the human or institutional position loses practical opportunities to exercise, verify, reconstruct, or contest the relevant capability, present performance can rise while the internally retained capacity for later independent epistemic action declines.*

Proposition 18.162 is a trajectory claim rather than a forecast for every use. Empirical evaluation should examine which capabilities are externalized, which new capabilities are learned, what fallback remains, and whether the resulting dependence is acceptable for the function's consequences.

The section has treated AI-mediated epistemic dependence as an economic architecture of knowledge production and retained capability. Machine mediation can expand access and performance while becoming historically embedded in workflows. Verification gaps can relocate burdens toward checking and responsibility. Interpretive dependence can narrow practical framing alternatives. Opacity can be governed through documentation, testing, monitoring, and appropriately scoped review even where exhaustive internal understanding remains unavailable. Infrastructure dependence makes continuity a property of the wider technical and organizational stack. Contestability supplies routes for challenge; audit creates structured external verification; and preservation of human epistemic agency keeps later orientation, judgment, recovery, and participation from being silently externalized along with current performance.

These dimensions are analytically connected but non-identical. Strong audit can coexist with weak human learning. High model transparency can coexist with infras-

structure dependence. Broad access can coexist with interpretive concentration. Human expertise can coexist with weak contestability when institutions deny standing to challenge. Robust epistemic governance therefore depends on the configuration of several capacities rather than on one ideal of transparency or autonomy.

Section 18.11 turns to the symbolic environment within which these dependencies operate. As synthetic text, images, evidence-like artifacts, and representations become abundant, authenticity, provenance, institutional verification, and the stability of representational signals acquire greater economic significance. The next section therefore examines symbolic abundance and representation as a distinct layer of AI-mediated economic order.

18.11 Symbolic Abundance and Representation

This section examines the economic organization of representation when artificial systems can generate text, images, evidence-like artifacts, and other symbolic forms at low marginal cost and high speed. Its role is to extend the analysis of symbolic abundance developed in Chapter 17 into the representational conditions of AI-mediated economic order. The objective is to distinguish several properties that become increasingly consequential when symbolic production expands: the production of synthetic representations, the stability of representational signals, authenticity, provenance, trust, institutional verification, and the capacity of representations to alter the relations they describe. The method is relational and historical. A representation is analyzed through its production history, its relation to an intended referent or evidential claim, the institutions that recognize it, the verification burden it creates, and the later decisions or relations generated through its use.

The section builds on three antecedents. Section 18.1 treated symbolic production as one component of artificial productive capacity while preserving the distinction between fluency and epistemic warrant. Section 18.10 then analyzed verification gaps, provenance, contestability, audit, and retained human epistemic agency under sustained AI mediation. Chapter 17 supplied the broader scarcity logic: increased symbolic abundance can relocate scarcity toward verification, attention, orientation, and trust. The present section focuses specifically on representation. Synthetic text and images can lower the cost of producing candidate explanations, depictions, simulations, summaries, records, and communicative artifacts. The same abundance can also reduce the informational value previously attached to the mere existence, polish, or apparent specificity of a representation.

The epistemic boundary is especially important. Fluent symbolic output does not by itself establish understanding, truth, or warranted knowledge (Bender et al. 2021). Contemporary provenance standards similarly distinguish verifiable claims about the origin, signing, or modification history of a digital asset from a general judgment that the asset is true, good, or trustworthy (Coalition for Content Provenance and Authenticity 2026). GRE therefore treats representational abundance as an economic transformation of the production, circulation, verification, and performative use of symbols rather than as evidence that representational uncertainty disappears.

Definition 18.163 (AI-mediated symbolic abundance). *AI-mediated symbolic abun-*

Table 18.11: Dimensions of symbolic abundance and representation in AI-mediated economic order. The dimensions separate production of synthetic artifacts from the epistemic and institutional conditions under which those artifacts become consequential.

Dimension	Representational object	Principal analytical concern
Synthetic text	Machine-generated or machine-transformed linguistic representation	Relation among fluency, authorship, warrant, context, and consequential use
Synthetic images	Generated or transformed visual representation	Relation among depictive plausibility, source history, referential status, and evidential interpretation
Synthetic evidence	Artificially generated, reconstructed, simulated, or transformed material introduced into an evidential chain	Clear typing of observation, simulation, illustration, reconstruction, and claim support
Representational instability	Declining reliability of familiar surface cues for inferring origin, effort, authorship, or evidential status	Relocation of verification from appearance toward provenance, context, and institutional process
Authenticity	Conformity between a declared identity or production history and the artifact presented	Authentication of source or history without automatic inference to substantive truth
Provenance	Reconstructible history of origin, transformation, custody, and relevant processing	Ability to trace how a representation acquired its current form and claims
Trust	Practical willingness to rely on a representation or representational institution under incomplete direct verification	Evidence, history, accountability, and fallback conditions supporting reliance
Institutional verification	Organized procedures for checking source, integrity, evidential role, compliance, or authenticity	Allocation of verification authority, burden, records, and contestability
Performative representation	Representation whose uptake changes later decisions, classifications, allocations, expectations, or relations	Feedback from symbolic representation into the relational field it helps organize

dance is a relational condition in which artificial generative capability materially lowers the cost, time, or specialized labor required to produce, vary, transform, or circulate representations across one or more symbolic modalities, thereby changing the relative scarcity of representation, verification, provenance, attention, interpretation, or institutional recognition.

Definition 18.163 concerns a change in the economic environment of representation. It allows symbolic artifacts to remain scarce in some domains because legal permission, specialist validation, trusted authorship, embodied observation, archival continuity, compute, or institutional acceptance can remain constrained even when raw generation becomes inexpensive.

Table 18.11 supplies the section's architecture. The dimensions overlap while remaining analytically distinct. Authentic content can be false. Provenance can be complete while an interpretation remains poor. A synthetic artifact can be accu-

rately labeled and still become performative. Institutional verification can improve trust while remaining contestable. The economic problem concerns the configuration through which these properties are produced, recognized, and acted upon.

18.11.1 Synthetic Text

Synthetic text changes the economics of linguistic representation because drafting, reformulation, translation, summarization, classification, dialogue, and stylistic variation can be produced at scales and speeds previously associated with substantially greater human labor. The productive gain is real even where epistemic quality varies. A generated paragraph can function as a draft, interface, advertisement, explanation, code comment, legal template, educational exercise, research prompt, or institutional communication before its truth conditions have been fully assessed.

The economic effect therefore depends on the role assigned to the text. Exploratory generation has a different verification burden from a signed contract, clinical recommendation, regulatory filing, archival record, or scientific claim. A human editor can use synthetic text as provisional symbolic material while retaining responsibility for factual and normative judgment. An organization can also operationalize generated text automatically, allowing a symbolic artifact to influence customers, employees, public decisions, or downstream systems before a human reviewer has examined it.

Definition 18.164 (Synthetic textual representation). A *synthetic textual representation* is a linguistic artifact whose materially relevant form, content selection, transformation, or sequencing is generated through an artificial system and whose economic role depends on how that artifact is interpreted, verified, attributed, circulated, or acted upon within a relational configuration.

The definition is intentionally broad enough to include fully generated text and materially transformed human text. The analytical question is the role of artificial generation in the representational chain, rather than a binary authorship label. A short machine translation and a fully generated report can require different attribution and verification practices even though both are synthetic in this bounded sense.

Synthetic text can also change the signal value of textual properties. Grammatical fluency, formatting quality, length, confidence of expression, and apparent comprehensiveness previously required some combination of skill, time, editing, organizational capacity, or access to expertise. Generative systems can lower the cost of producing those manifestations. The properties can remain useful, yet their evidential relation to expertise, effort, or warrant can weaken.

Proposition 18.165 (Textual signal-relocation condition). *Where artificial generation materially lowers the cost of producing a textual feature that previously contributed to judgments of expertise, effort, credibility, or organizational capacity, the informational value of that feature becomes more dependent on complementary signals such as provenance, demonstrated competence, source support, accountability, historical performance, or institutional verification.*

Proposition 18.165 does not imply universal signal collapse. Expert writing can retain distinctive value through reasoning, judgment, source selection, problem formation, responsibility, or context. The proposition concerns a shift in the inference

supported by surface form alone.

18.11.2 Synthetic Images

Synthetic images extend the same transformation into visual representation. Artificial systems can generate, modify, reconstruct, enhance, segment, stylize, or compose images that participate in design, education, advertising, simulation, planning, entertainment, documentation, and analysis. Visual plausibility therefore becomes increasingly separable from the historical relation between an image and a photographed event, place, person, object, or measurement process.

The relevant distinction is representational status. A generated architectural visualization can be useful precisely because it depicts something that does not yet exist. A synthetic training image can support model development without claiming to document a historical event. A reconstructed image can clarify a damaged record while requiring disclosure of what was inferred. A visual presented as direct documentary evidence carries a different source claim. Economic analysis should therefore preserve the declared function of the image rather than classify synthetic imagery as inherently deceptive or inherently non-evidential.

Definition 18.166 (Synthetic visual representation). *A synthetic visual representation is a visual artifact whose materially relevant pixels, depicted structures, or compositional relations are generated or transformed through an artificial system and whose referential or evidential status depends on the declared relation among the artifact, its source material, its production process, and the object or event it is used to represent.*

A single image can occupy several roles across contexts. A generated scene can be a design proposal in one context, an illustrative figure in another, and misleading pseudo-documentation if later detached from its production history. Provenance and contextual continuity therefore matter because circulation can change the role assigned to the same artifact.

Visual abundance also changes verification costs. Human observers often rely on visual coherence as a rapid plausibility cue. When synthetic systems can reproduce many familiar cues, visual inspection alone can support weaker inference about production history. Institutions can respond through retained source files, signed capture workflows, content credentials, chain-of-custody records, or independent corroboration, depending on consequence and feasibility.

Proposition 18.167 (Visual plausibility–provenance separation). *As artificial generation expands the set of visually plausible artifacts, visual plausibility and production provenance become increasingly separable analytical properties; consequential uses therefore require verification practices calibrated to the source-history claim carried by the image.*

The proposition concerns verification architecture rather than a prediction that direct visual evidence loses all value. Images embedded in accountable production systems can remain highly informative. The economic transformation lies partly in the rising importance of the system around the image.

18.11.3 Synthetic Evidence

The term *synthetic evidence* requires particular care because generation and evidence occupy different analytical levels. An artifact becomes evidence only relative to a claim, an inference rule, a method, and an institutional or scholarly context. Artificial systems can nevertheless generate or transform artifacts that enter evidential chains: simulated observations, reconstructed records, synthetic datasets, generated comparison cases, imputed values, translated testimony, enhanced images, summarized documents, or machine-generated classifications.

Many such artifacts are legitimate epistemic instruments when their status is explicit. Simulation can provide evidence about the consequences of a model under declared assumptions. Synthetic data can support testing or privacy-preserving development. Reconstruction can help recover damaged material. Imputation can permit statistical analysis under stated missing-data assumptions. The epistemic problem arises when the generated or transformed status becomes difficult to distinguish from direct observation, or when downstream users infer a stronger evidential relation than the production process supports.

Definition 18.168 (Synthetic evidential artifact). A *synthetic evidential artifact* is an artificially generated, reconstructed, transformed, simulated, or imputed representation that enters an evidential chain supporting a claim and whose warranted use depends on preserving the relation among its production procedure, underlying source material, assumptions, uncertainty, and intended inferential role.

This definition avoids treating every generated artifact as evidence. A fictional illustration becomes evidential only if an inquiry uses it to support a claim. The inferential role therefore belongs to the complete evidence-to-claim architecture.

Documentation practices become important because synthetic transformations can be difficult to detect after aggregation. Dataset documentation provides one precedent for recording motivation, composition, collection, processing, and recommended uses (Geburu et al. 2021). The same principle can be extended to synthetic evidence: later users need enough history to determine what was observed, what was generated, which assumptions entered the transformation, and which uncertainty was introduced.

Proposition 18.169 (Synthetic-evidence typing condition). A *synthetic evidential artifact supports reconstructible inquiry more strongly when the evidential chain preserves a declared type for the artifact, the source material and transformations on which it depends, the assumptions governing generation or reconstruction, and the claim-relative uncertainty introduced by those operations.*

This condition supports later re-epistemization. An artifact can acquire new evidential value when methods improve, yet that reanalysis requires enough provenance to distinguish original observation from later synthetic transformation.

18.11.4 Representational Instability

Symbolic abundance can produce *representational instability*: familiar features of representation no longer support the same inference about origin, authorship, effort, expertise, or evidential status that they supported under an earlier production

regime. Instability does not mean that representation itself becomes impossible. It means that some mapping between observable symbolic form and the hidden process that generated it becomes less reliable.

This instability can be modality-specific. Linguistic fluency can become cheap while deep domain verification remains expensive. Photorealistic appearance can become easy to synthesize while authenticated capture remains institutionally costly. Detailed citations can be generated while source checking remains scarce. Personalized explanation can scale while responsibility for consequential advice remains concentrated. The scarcity structure therefore shifts from production toward discrimination among representations and reconstruction of their histories.

Definition 18.170 (Representational instability). *Representational instability* is a historically relative condition in which one or more observable properties of a representation cease to support a previously relied-upon inference about its origin, authorship, production cost, epistemic status, or institutional standing with comparable reliability under the new symbolic-production regime.

Representational instability is relational because the same artifact can remain stable within one authenticated institution while becoming ambiguous in open circulation. A signed archival record can preserve source continuity even as visually similar unsigned copies proliferate. A professional certification can maintain institutional force even when documents imitating its visual form become cheap to generate. The relevant stability lies in the relation among representation, production history, and verification institution.

Proposition 18.171 (Verification-relocation under representational instability). *Where representational instability weakens surface-form cues, verification effort tends to relocate toward production history, contextual consistency, independent corroboration, authenticated identity, institutional process, or other relations whose cost has not fallen at the same rate as symbolic generation.*

The proposition is conditional because new surface cues can also emerge. Watermarks, standardized labels, or machine-detection tools can become part of verification practice. Their effectiveness remains historically contingent as generation and detection technologies co-evolve.

18.11.5 Authenticity

Authenticity concerns whether an artifact or identity is what the relevant claim says it is. In an AI-mediated symbolic economy, authenticity becomes important because synthetic systems can generate convincing representations of styles, voices, documents, images, or organizational forms. The relevant authenticity claim can concern origin, authorship, identity, continuity, capture, modification history, or institutional issuance.

Authenticity should remain separate from truth. An authentic statement by a person can be false. An authentic photograph can be miscaptioned. An authentic institutional document can contain an error. Conversely, a synthetic reconstruction can accurately represent a historical structure while lacking the status of an original artifact. Authentication therefore resolves a source or identity claim within a declared

scope; it does not settle the substantive adequacy of the represented content.

Definition 18.172 (Representational authenticity). *Representational authenticity* is the warranted conformity between a representation and a declared claim concerning its source identity, authorship, production event, capture process, issuance, or transformation history, evaluated under a specified authentication procedure and scope.

The definition permits multiple authenticities. A document can be authentic with respect to institutional issuance while its embedded image has a different transformation history. A transcript can authentically record a model output while the model output itself contains unsupported claims. Complex artifacts therefore benefit from component-level or event-level provenance where the consequences justify the additional detail.

Proposition 18.173 (Authenticity–truth non-equivalence). *Successful authentication of a representation strengthens the warranted claim about the artifact’s declared source or production history while leaving substantive truth, evidential adequacy, normative acceptability, and downstream interpretation to additional evaluation.*

This distinction aligns directly with contemporary provenance standards, which can verify signed assertions about content history while explicitly avoiding a general truth judgment (Coalition for Content Provenance and Authenticity 2026). The economic value of authentication lies in reducing uncertainty about one part of the representational chain.

18.11.6 Provenance

Provenance extends authenticity from a local source claim to a history. A provenance record can identify origin, custody, transformations, tools, versions, signatures, data sources, or institutional events through which a representation acquired its current form. In a symbolic-abundance environment, this history can become economically valuable because representations are easily copied, transformed, detached from context, recombined, or reissued through new interfaces.

Contemporary content-provenance standards demonstrate one technical route through cryptographically verifiable metadata, signatures, and bindings between assertions and digital assets (Coalition for Content Provenance and Authenticity 2026). Dataset documentation offers another route focused less on cryptographic continuity and more on motivation, composition, collection, processing, and intended use (Gebru et al. 2021). These approaches perform different functions. GRE treats provenance as a plural architecture whose adequate form depends on what later inquiry needs to reconstruct.

Definition 18.174 (Representational provenance architecture). *A representational provenance architecture* is the organized set of records, identifiers, metadata, signatures, custody relations, transformation logs, source links, and institutional practices through which the materially relevant history of a representation can be reconstructed across production, modification, circulation, and use.

Provenance can be incomplete while still useful. The appropriate granularity depends on consequence, cost, privacy, security, and feasibility. A creative image used

for entertainment can require little history. A scientific figure, court exhibit, public record, or financial authorization can justify much stronger continuity. More provenance is therefore not automatically better when recording itself creates privacy, surveillance, or security burdens.

Proposition 18.175 (Provenance-value condition). *The economic and epistemic value of provenance rises when consequential users need to distinguish among materially different production histories that cannot be inferred reliably from the representation's surface form and when the expected benefit of reconstructibility exceeds the relevant recording, privacy, security, interoperability, and maintenance costs.*

Provenance can also support attribution and compensation. Where an artifact is derived from several sources, a preserved transformation history can make some contribution relations inspectable. The record does not itself settle legal ownership, authorship, or distributive claims, yet it can supply evidence required for those institutions to operate.

18.11.7 Trust

Symbolic abundance increases the importance of trust because direct verification cannot scale with every representation encountered. Individuals and institutions necessarily rely on delegated verification, reputation, professional roles, authenticated channels, historical performance, and institutional procedures. The economic problem is therefore to organize warranted reliance under incomplete direct checking.

Trust in representation can attach to different objects. A person can trust an author, a publisher, a model provider, a provenance system, a certification institution, an archival repository, a professional community, or a particular artifact history. These objects can diverge. A trusted institution can issue a contested claim. A reliable provenance chain can lead to a source that is itself unreliable. A high-performing model can operate inside an institution with poor accountability. Representational trust therefore benefits from explicit typing.

Definition 18.176 (Representational trust relation). *A representational trust relation is a historically situated willingness by a position to rely on a representation, source, channel, or verification institution for a declared function under incomplete direct verification, supported by an evidential, relational, contractual, professional, or institutional basis that makes the reliance practically intelligible.*

Trust can economize on verification costs while also creating vulnerability. If a trusted channel becomes compromised, the efficiency created by concentrated reliance can amplify error. Distributed verification can reduce some common-mode risks while raising coordination costs. Institutional design therefore concerns the structure and revisability of trust rather than maximal trust in every source.

Proposition 18.177 (Trust diversification condition). *Where consequential representation depends heavily on one source, model, authentication service, or institutional verifier, additional independent routes of corroboration, contestation, or recovery can reduce the extent to which failure of that trusted position deforms the wider system's epistemic possibilities.*

The proposition is compatible with specialization. Independent corroboration need not reproduce the complete production process. It requires enough alternative evidence or institutional standing to detect and act on materially important failures.

18.11.8 Institutional Verification

Institutional verification becomes more important when the volume of representations exceeds individual checking capacity. Archives, publishers, courts, scientific communities, news organizations, certification bodies, platforms, regulators, professional associations, and technical provenance services can each verify different properties. Their roles include identity authentication, source checking, evidence review, methodological validation, signature verification, chain-of-custody preservation, correction, and public contestation.

Institutional verification should be understood as a division of epistemic labor. Standardized procedures can support impersonal and portable judgment, a role historically associated with institutional forms of quantitative objectivity (Porter 1995). In AI-mediated representation, verification institutions can similarly reduce the burden on each recipient by establishing shared rules for provenance, disclosure, correction, or evidential status. Their authority remains itself a relational object whose competence, independence, accountability, and contestability require evaluation.

Definition 18.178 (Institutional representational verification). *Institutional representational verification* is an organized procedure through which an institution with declared competence, authority, or responsibility evaluates specified properties of a representation or its history and issues a record, judgment, credential, correction, or access decision that can be relied upon by positions unable or unwilling to reproduce the complete verification process independently.

Verification institutions can become bottlenecks. If only one platform can authenticate a widely used identity or one proprietary service can validate provenance, the institution gains control over which representations receive trusted standing. Conversely, fragmented verification can produce incompatible standards and high coordination costs. Governance must therefore consider interoperability, appeal, independent audit, preservation, and the possibility of institutional error.

Proposition 18.179 (Institutional verification reliability condition). *Institutional verification supports robust representational trust more strongly when the verifying institution has adequate competence and evidence access, preserves reconstructible records, distinguishes the property actually verified from stronger unverified claims, exposes material conflicts or uncertainty, and provides practical routes for correction, appeal, or independent review.*

The condition is deliberately property-specific. A service that verifies cryptographic provenance should not be treated automatically as verifying factual truth. A publisher that checks identity and format may not have reproduced an empirical result. Explicit scope keeps verification from silently expanding into generalized authority.

18.11.9 Performative Synthetic Representation

Synthetic representation becomes especially important for GRE when it enters the generative dynamics of the system it represents. A generated credit narrative can affect lending; a synthetic risk score can alter insurance or employment; an AI-generated market summary can influence trading or expectations; a generated institutional profile can affect eligibility; a synthetic image can alter reputation; and an automated classification can change which later actions become available. In such cases the representation is economically consequential because actors and institutions respond to it.

Chapter 16 treated comparison structures and manifested representations as potentially reflexive when their uptake changes later relational configurations. The same logic applies here. The synthetic origin of a representation does not by itself make it performative. Performative status arises from the coupling between representation and consequential response.

Definition 18.180 (Performative synthetic representation). *A performative synthetic representation is an artificially generated or materially AI-transformed representation whose institutional or social uptake contributes causally and generatively to a change in later classifications, allocations, expectations, admissible operations, reputational positions, decisions, or other relational conditions retained by the analysis.*

The definition includes beneficial and harmful effects. A generated accessibility description can improve participation; a synthetic translation can enable coordination; an automatically generated alert can prevent loss. A poor representation can also reproduce exclusion or create false expectations. Performative analysis therefore asks how the representation enters a decision pathway and which feedback mechanisms reproduce or revise its effects.

Proposition 18.181 (Synthetic-representation feedback condition). *A synthetic representation becomes part of a self-reinforcing relational feedback when its uptake changes the later configuration in ways that increase the probability, authority, visibility, or institutional use of representations generated under the same or a related representational scheme.*

Examples can include classifications that alter the data later used to retrain a system, generated rankings that redirect attention toward already visible entities, or automated reports whose categories become embedded in subsequent administrative practice. The proposition identifies a feedback architecture rather than a necessary tendency toward amplification; later effects can also weaken, contest, or redirect the original scheme.

Proposition 18.182 (Representational governance condition). *Where synthetic representations enter consequential feedback loops, robust governance requires attention to both artifact-level properties such as provenance and authenticity and system-level properties such as contestability, verification authority, correction, record preservation, affected-party participation, and the possibility of revising the representational scheme itself.*

The system-level condition prevents provenance from becoming an exhaustive solution. An artifact can have impeccable provenance while the classification scheme, institutional objective, or decision rule remains poorly justified. Conversely, an in-

stitution can use a valuable representational scheme while failing to preserve the provenance needed to contest a particular application. The two levels are complementary.

The section has treated symbolic abundance as a reorganization of representational scarcity. Synthetic text and images reduce production costs while weakening some historical surface cues of authorship, effort, or source history. Synthetic evidential artifacts can support legitimate inquiry when their generated status, assumptions, uncertainty, and role remain reconstructible. Representational instability relocates verification toward provenance and institutional process. Authenticity concerns source or production-history claims, while truth and evidential adequacy require additional evaluation. Provenance preserves the history through which an artifact acquired its form. Trust organizes practical reliance when direct verification is incomplete. Institutional verification distributes verification labor while creating new questions of authority and contestability. Performative synthetic representations close the loop by entering the relational dynamics they help describe.

These developments make symbolic abundance an orientation problem as well as a verification problem. When candidate representations, explanations, problems, simulations, and arguments can be generated rapidly, scarce judgment increasingly concerns which representations deserve sustained inquiry and action. Section 18.12 therefore turns to AI and research orientation, examining problem generation, difficulty, aesthetic and generative judgment, historical and relational sensitivity, and human responsibility for orienting inquiry within an abundant symbolic field.

18.12 AI and Research Orientation

Sections 18.9–18.11 examined human–AI relational economies, epistemic dependence, and symbolic abundance. The present section turns to a different consequence of abundant machine generation: the orientation of inquiry itself. Its role is to analyze how AI changes the practical supply of candidate problems, representations, explanations, conjectures, experiments, simulations, and intervention pathways while leaving the selection of worthwhile trajectories dependent on judgment that is historically, relationally, and institutionally situated. The objective is neither to repeat the earlier analysis of curiosity and question formation nor to restate the general methodology of research praxis. Chapter 6 established judgment and orientation as components of research praxis, Chapter 8 developed the generative research question, and Chapter 17 examined curiosity, research taste, and aesthetic orientation within the epistemic economy. The present section asks how those capacities are reorganized when machine systems can generate candidate research and action possibilities at very low marginal cost.

The discussion proceeds through nine analytical steps. It begins with problem generation and the resulting abundance of difficult problems. It then separates difficulty from worth, examines the role of aesthetic judgment, and develops historical and relational sensitivity as conditions of orientation. The section subsequently formulates generative judgment as an assessment of possible future-opening effects, locates responsibility for consequential orientation within human and institutional relations,

Table 18.12: Dimensions of AI-mediated research orientation.

Dimension	Orientation function	Principal analytical question
Problem generation	Expands candidate questions and problem formulations	Which candidates become thinkable, legible, and comparable?
Difficult-problem abundance	Enlarges the set of tractable or expressible hard problems	Which scarce capacities become the new bottlenecks after generation becomes cheap?
Research-worth assessment	Separates technical hardness from epistemic or social significance	Which criteria justify sustained commitment to a difficult problem?
Aesthetic judgment	Orients attention through elegance, depth, surprise, coherence, or beauty	When does aesthetic attraction reveal generative structure, and when does it mislead?
Historical sensitivity	Locates a problem within accumulated paths, exclusions, prior attempts, and changing meanings	What history is required to understand why the problem has its present form?
Relational sensitivity	Preserves dependencies, affected positions, institutions, and cross-level relations	Which materially relevant relations disappear under a generated framing?
Generative judgment	Assesses the possibility of opening later questions, methods, capacities, or relations	Which trajectories plausibly enlarge future epistemic or practical possibility?
Human responsibility	Retains accountable commitment, contestation, and reason-giving for orientation	Who can justify, revise, and bear responsibility for committing resources to a trajectory?
Potential reweighting	Changes the relative salience and support of research and action trajectories	How does AI-mediated orientation alter later allocation, capability, and feedback?

and concludes with a model of AI-mediated reweighting over research and action possibilities. The method is relational and allocation-sensitive. AI systems are treated as participants in an orientation architecture whose outputs acquire practical significance only through their coupling with researchers, institutions, communities, infrastructures, evaluative practices, and downstream decisions.

Definition 18.183 (AI-mediated research orientation). *AI-mediated research orientation* is the historically situated process through which artificial-intelligence systems materially affect which research or action possibilities become visible, comparatively salient, articulable, evaluable, supportable, or institutionally actionable while the significance of those possibilities remains dependent on wider human, relational, and institutional judgment.

Definition 18.183 assigns AI an orientation-relevant role without treating generated rankings or suggestions as self-justifying research priorities. A system can enlarge the candidate field, compress search time, expose remote analogies, or make one trajectory easier to articulate. Those changes can alter what receives attention even before a formal choice is made.

Table 18.12 summarizes the nine dimensions developed below.

The rows in Table 18.12 form an architecture rather than a mandatory sequence. A historically significant problem can arise before it is recognized as difficult. Aesthetic attraction can precede formal problem articulation. Relational sensitivity can reveal that a technically elegant problem has been framed at the wrong level. Insti-

tutional commitment can also feed back into the candidate field by generating new data, methods, personnel, or infrastructures. Orientation is therefore a generative allocation problem over a changing field rather than a one-time act of selection.

Proposition 18.184 (Orientation-stage separation). *Problem generation, problem difficulty, judgments of worth, orientation criteria, resource commitment, and realized downstream value should remain analytically distinct where they depend on different evidence, relations, time horizons, or institutional mechanisms.*

Proposition 18.184 is especially important under AI abundance. A system can generate thousands of apparently sophisticated problems without establishing that any one of them deserves sustained inquiry. Conversely, a low-complexity question can possess high epistemic or practical significance because of its historical position, neglected relational consequences, or capacity to reorganize later inquiry.

18.12.1 Problem Generation

Research orientation begins before a project has acquired a stable question. Earlier chapters treated problem formation as a generative activity in which encounters, salience, conceptual resources, practical tensions, and inherited disciplinary structures interact. AI changes this activity by increasing the number and variety of candidate formulations that can be produced from a given body of material. A researcher can ask a model to generate counterexamples, alternative hypotheses, unsolved variants, cross-disciplinary analogies, possible mechanisms, missing cases, or research questions derived from a literature map. These operations can enlarge the space of articulated problems more rapidly than unaided deliberation alone.

The resulting expansion should be distinguished from discovery of genuinely valuable problems. A generated problem can be grammatically coherent, technically difficult, and locally novel while reproducing an unimportant distinction, neglecting a historically settled limitation, or lacking access to the phenomena required for meaningful investigation. The economic significance of machine generation lies first in the changed cost of candidate production.

Definition 18.185 (AI-expanded problem field). *An AI-expanded problem field is a model-relative set of research or action problems whose practical availability to a researcher, organization, or community has been enlarged through AI-supported generation, reformulation, search, translation, comparison, simulation, or recombination.*

Definition 18.185 concerns practical availability rather than intrinsic existence. A problem may have been implicit in prior materials for decades yet become newly actionable because a model makes the relevant comparison, formulation, or cross-domain analogy inexpensive to construct. Machine mediation can therefore change the effective frontier of problem articulation even where the underlying phenomena and records are unchanged.

This capability can reduce several traditional bottlenecks. Researchers can explore alternative framings before committing to one. Students can externalize weakly formed questions and compare them. Small teams can generate candidate experiments or formal variants that previously required broader specialized labor. Multilingual generation can expose problem formulations across linguistic boundaries.

The benefit is partly option value: more candidate trajectories can be inspected before scarce long-horizon resources are committed.

Expansion also creates new selection costs. A candidate field can grow faster than the capacity to verify novelty, assess significance, reconstruct historical context, judge feasibility, or identify affected relations. The research system can therefore move from a scarcity of candidate problems toward a scarcity of orientation.

Proposition 18.186 (Problem-generation expansion). *Where AI reduces the marginal cost of generating, reformulating, or comparing candidate problems, the principal orientation bottleneck can shift from candidate production toward discrimination among candidates, provided that verification, historical reconstruction, relational interpretation, and resource commitment remain comparatively costly.*

The proposition is conditional because some domains continue to face scarcity of observations, instruments, access, or formalizable problems. AI cannot generate a missing archaeological record or replace a field site that was never observed. It can nevertheless change the organization of inquiry around the materials that exist.

18.12.2 Abundance of Difficult Problems

Machine-assisted problem generation changes the meaning of difficulty as an orienting signal. Historically, technical difficulty can itself have functioned as a filter because only a limited number of researchers possessed the knowledge, mathematical skill, computational resources, or time required to formulate and pursue certain problems. AI can weaken parts of this filter by supplying code, formal manipulations, candidate proofs, simulations, translations, literature synthesis, and procedural guidance. The number of difficult-looking problems that can be stated and partially explored can therefore increase substantially.

The result is an *abundance of difficult problems*: a research environment in which the ability to find or articulate technically demanding tasks grows faster than the capacity to justify why those tasks matter. Getzels and Csikszentmihalyi's work on problem finding emphasizes that creativity involves the formation and selection of problems as well as their solution (Getzels and Csikszentmihalyi 1976). AI-mediated research intensifies this distinction because problem production itself becomes increasingly automatable.

Definition 18.187 (Difficult-problem abundance). *Difficult-problem abundance* is a condition in which a research system can generate or access more technically demanding, cognitively complex, computationally intensive, or procedurally elaborate candidate problems than it can responsibly evaluate, resource, verify, or sustain over the relevant horizon.

The definition is deliberately capacity-relative. What counts as difficult changes with tools, expertise, infrastructure, and organization. A theorem-search problem that was previously inaccessible can become routine after improvements in automated reasoning. A literature-comparison task can become cheap after language-model integration. At the same time, empirical identification, field access, measurement design, causal inference, or institutional coordination can remain difficult.

Difficult-problem abundance can alter incentives. Technical sophistication may be-

come less informative as a signal of researcher capability when systems can cheaply generate sophisticated-looking artifacts. Evaluation can shift toward question formation, model choice, verification, explanatory depth, integration with evidence, historical understanding, and the ability to recognize when a difficult problem is poorly posed. Symbolic diagnosticity can therefore decline in the same way that Chapter 17 described symbolic inflation more generally.

Proposition 18.188 (Difficulty-signal erosion). *When AI substantially lowers the cost of producing technically sophisticated candidate problems or partial solutions, observed difficulty can lose some of its diagnostic value as a signal of research worth or researcher capability unless the evaluation process separately examines problem formation, verification, evidential connection, and downstream significance.*

The proposition does not imply that difficulty becomes irrelevant. Some difficult problems remain deeply important precisely because they block major scientific, mathematical, institutional, or practical progress. The point is that difficulty alone becomes a weaker allocation rule when difficult candidates are abundant.

18.12.3 Research-Worth Assessment

The abundance of difficult problems makes a long-standing distinction more economically consequential: technical difficulty and research worth are different properties. A problem can be hard because the representation is inefficient, because the search space is large, because the data are scarce, because the institutional coordination burden is high, or because the underlying phenomenon genuinely resists explanation. None of these conditions independently establishes that solving the problem would create substantial epistemic or social value.

Research worth is therefore better represented as a profile than as a scalar derived from difficulty. Relevant dimensions can include epistemic significance, neglectedness, evidential accessibility, methodological value, capacity formation, public or ecological consequence, preservation value, relational reach, reversibility of error, and generative promise. Different institutions can legitimately weight these dimensions differently, and some dimensions can remain incomparable.

Definition 18.189 (Research-worth profile). *A research-worth profile is a declared, revisable representation of the reasons for sustaining inquiry into a candidate problem, including the epistemic, relational, historical, methodological, practical, normative, or generative considerations treated as relevant by the evaluating community or institution.*

The profile is a judgment aid rather than an objective universal ranking. It makes the basis of orientation inspectable. A mathematical problem can be worth pursuing because it opens a new structure even without immediate application. A social problem can be worth pursuing because it affects a weakly represented population even when the publication payoff is low. A methodological replication can be worth pursuing because it stabilizes the evidential infrastructure of a field. A technically easy question can therefore outrank a much harder one under a declared orientation profile.

Proposition 18.190 (Difficulty-worth separation). *Technical or cognitive difficulty*

supplies evidence about the resources required to solve or investigate a problem, while research worth requires additional judgment concerning the significance, consequences, relations, histories, and future possibilities associated with that problem.

This distinction also limits optimization toward benchmark-like research. If an AI system is rewarded for generating problems of calibrated difficulty, it can produce tasks that are challenging under the benchmark while remaining weakly connected to the wider research field. Human and institutional judgment is required to determine whether the challenge belongs to a trajectory worth sustaining.

18.12.4 Aesthetic Judgment

Chapter 17 developed aesthetic judgment as one component of epistemic orientation. Beauty, elegance, surprise, depth, and research taste can influence where inquiry goes when explicit warrant remains incomplete, while remaining distinct from truth and realized value. AI abundance gives this judgment a new role because candidate formulations, proofs, visualizations, hypotheses, and theoretical combinations can be produced rapidly and in polished form.

Aesthetic judgment can help compress a large candidate field. A concise representation can reveal invariant structure. An elegant proof strategy can make previously hidden relations visible. A surprising analogy can expose a new research direction. A sense of depth can motivate sustained attention to a problem whose consequences are not yet fully articulated. McAllister's account of scientific aesthetics is useful here because aesthetic preferences can be historically formed within scientific communities rather than functioning as timeless indicators of truth (McAllister 1996).

AI also creates a risk of aesthetic inflation. Fluent language, visually coherent diagrams, smooth formal notation, and apparently elegant synthesis can be generated without the resistant historical work through which researchers traditionally acquired confidence in an argument. Surface elegance can therefore become cheaper than structural adequacy.

Definition 18.191 (Aesthetic orientation under machine abundance). *Aesthetic orientation under machine abundance* is the use of historically formed judgments of elegance, beauty, surprise, coherence, depth, or related qualities to discriminate among AI-generated or AI-mediated research possibilities while preserving independent evaluation of evidential adequacy, conceptual validity, and generative consequence.

Proposition 18.192 (Aesthetic filtering condition). *Aesthetic judgment contributes most defensibly to AI-mediated research orientation when it functions as a revisable exploratory filter whose selections remain exposed to verification, historical comparison, competing representations, and empirical or formal correction.*

The condition gives aesthetic judgment a positive role without granting it final authority. Machine abundance can make cultivated taste more valuable precisely because aesthetic judgment can rapidly narrow a candidate field, yet the same abundance makes correction essential because polished form is easier to manufacture.

18.12.5 Historical Sensitivity

Research orientation becomes shallow when problems are detached from the histories through which they acquired their present form. AI systems can retrieve large literatures and reconstruct timelines, but generated summaries can compress away failed programs, excluded questions, institutional struggles, changing terminology, abandoned methods, or reasons why a problem was previously considered unproductive. Historical sensitivity therefore becomes a distinct orientation capability.

Kuhn's account of scientific change emphasizes that research problems acquire meaning within historically structured paradigms and practices (Kuhn 1962). Frickel and colleagues' work on undone science further shows that research agendas contain structured absences as well as completed work (Frickel et al. 2010). These insights are especially relevant in AI-mediated orientation because a system trained primarily on the recorded literature can reproduce the visibility structure of that literature. Highly documented questions become easy to regenerate, while weakly documented absences can remain difficult to notice.

Definition 18.193 (Historical sensitivity in AI-mediated orientation). *Historical sensitivity in AI-mediated orientation* is the capacity to evaluate a research possibility in relation to the paths, prior attempts, exclusions, conceptual changes, institutional conditions, evidential losses, and inherited commitments through which the present problem field was formed.

Historical sensitivity can change judgments of worth. A question that looks new under contemporary vocabulary can reproduce an older debate. A technically unfashionable line can become important because earlier abandonment reflected infrastructure limits that have since changed. A neglected archive can reveal that a field's current categories excluded relevant phenomena. Historical reconstruction can therefore alter both the candidate set and the weights assigned to candidates.

Proposition 18.194 (Historical-orientation condition). *Where the significance or novelty of a candidate research direction depends materially on earlier inquiry, institutional history, excluded evidence, or changing conceptual structure, responsible AI-mediated orientation requires enough historical reconstruction to distinguish rediscovery, repetition, continuation, reversal, and genuinely new possibility.*

The requirement is proportional rather than exhaustive. A research team does not need total historical recovery before acting. It needs enough history to avoid treating the generated present as if it were self-explanatory.

18.12.6 Relational Sensitivity

AI-generated problems often inherit the representational structure of their inputs. A dataset can make individuals visible while suppressing institutions. A language model can frame a governance problem as a preference problem. A simulation can isolate variables that are tractable while excluding relations that are constitutive of the phenomenon. Relational sensitivity asks whether the candidate problem preserves the relations that make the object economically, socially, or epistemically what it is.

Chapter 6 established relational sensitivity as a requirement of research praxis,

and Chapters 16–17 showed how power and epistemic position can be hidden by apparently neutral representations. Section 18.11 further showed that synthetic representations can become performative once institutions act on them. Research orientation therefore requires inspection of the relations preserved and omitted by generated framings.

Definition 18.195 (Relational sensitivity in AI-mediated orientation). *Relational sensitivity in AI-mediated orientation* is the capacity to assess whether an AI-generated or AI-mediated problem formulation adequately retains the dependencies, histories, institutions, affected positions, asymmetries, cross-scale interactions, and other relation types materially relevant to the inquiry.

Relational sensitivity can redirect inquiry across scales. A question about individual learning outcomes can become a question about platform design, school resources, language access, or family time once the relevant relations are represented. A question about productivity can become a question about ownership and surplus. A question about model accuracy can become a question about institutional verification or contestability. The shift does not invalidate the narrower problem; it identifies a larger field in which its significance can be evaluated.

Proposition 18.196 (Relational-coverage condition). *When materially relevant relations are omitted by a candidate problem representation, orientation based solely on that representation can systematically misallocate inquiry or action even if the retained variables are modeled accurately.*

The proposition identifies an orientation error rather than a universal requirement to model everything. Good inquiry selects a tractable subset of relations. Relational sensitivity requires that the exclusions remain visible enough to judge whether the simplification changes the problem's meaning or consequences.

18.12.7 Generative Judgment

Generative judgment evaluates a research or action trajectory partly by the future possibilities it may open. Chapter 17 introduced generative promise as an anticipatory judgment concerning possible new questions, methods, relations, capabilities, collaborations, applications, or reinterpretations. AI makes this dimension more important because candidate generation can become abundant while long-horizon commitment remains scarce.

A candidate can have generative promise even when its immediate deliverable is modest. A new measurement method can open a previously inaccessible empirical domain. A conceptual distinction can reorganize several debates. A public dataset can support later work by many groups. A careful negative result can close an unproductive branch and redirect resources. A theoretical synthesis can make new cross-disciplinary questions possible. The relevant value lies in transformations of later inquiry, not only in the current artifact.

Definition 18.197 (Generative judgment under AI mediation). *Generative judgment under AI mediation* is the assessment of whether an AI-generated or AI-mediated research or action possibility plausibly expands, reorganizes, or preserves later epistemic, methodological, relational, institutional, or practical possibilities beyond the

immediate output under consideration.

Generative judgment should also remain separate from novelty. AI can recombine distant literatures in ways that appear novel while producing little durable capacity. Conversely, a replication infrastructure or preservation project can look conventional while creating substantial future option value.

Proposition 18.198 (Generative-promise separation). *Generative promise is an anticipatory orientation judgment concerning possible future-opening effects; realized generative value requires later evidence that the supported trajectory actually created, preserved, or reorganized consequential possibilities.*

The proposition prevents the language of generativity from becoming self-validating. AI can help produce speculative maps of future possibility, but the maps remain hypotheses whose quality should be revised as histories unfold.

Generative judgment also creates a portfolio problem. Institutions can support some projects for immediate reliability, some for infrastructure, some for neglected needs, some for exploratory novelty, and some for long-horizon generative promise. AI can assist comparison among these roles, yet a portfolio still requires a normative and strategic judgment concerning which future possibilities a community wishes to keep open.

18.12.8 Human Responsibility for Orientation

AI can rank research topics, propose experiments, forecast publication impact, identify benchmark gaps, recommend grants, summarize policy priorities, or generate intervention options. Such systems can materially influence orientation even when the final decision is formally made by a human committee. Responsibility therefore depends on the architecture of decision formation rather than on the presence of a nominal human approval step.

Chapter 6 already established a non-delegation principle for final problem responsibility. The present chapter strengthens the economic interpretation. Orientation allocates scarce attention, careers, public funds, experimental risk, data collection, institutional capacity, participant burden, and future research infrastructure. These commitments can generate path dependence. A funded direction develops tools and communities that make its continuation easier; an unfunded direction can lose expertise, records, or visibility. Orientation is therefore a consequential allocation of future possibility.

Definition 18.199 (Orientation responsibility). *Orientation responsibility is the answerable human and institutional responsibility for committing consequential attention, resources, authority, participant involvement, or action capacity to a research or intervention trajectory, including responsibility for the reasons, exclusions, uncertainties, foreseeable consequences, and revision mechanisms associated with that commitment.*

The definition does not require an isolated human sovereign. Responsibility can be distributed among researchers, affected communities, funders, institutions, reviewers, regulators, professional bodies, and public processes. The relevant feature is the presence of relations capable of giving reasons, receiving contestation, revising pri-

orities, and bearing institutional responsibility for consequences. Longino's account of the social dimensions of scientific knowledge supports the importance of criticism and community interaction in such judgment (Longino 1990).

Proposition 18.200 (Responsibility-retention condition). *Where AI materially shapes the ranking, formulation, or recommendation of consequential research and action possibilities, responsible orientation requires identifiable human and institutional positions with practical authority to inspect the basis of the recommendation, contest its framing, revise or reject it, and remain answerable for the resulting commitment.*

This requirement is stronger than keeping a human in the loop procedurally. A reviewer who lacks time, information, alternatives, or institutional authority may merely ratify a machine-generated priority. Responsibility requires effective rather than symbolic capacity to orient.

18.12.9 Research–Action Potential Reweighting

The preceding subsections can be integrated through a minimal reweighting model. The model is intended to represent orientation effects rather than intrinsic value. Let $\mathcal{T}(C)$ denote a declared finite or countable family of research and action trajectories practically available in a configuration C . A trajectory can be a research question, experimental programme, theoretical line, institutional reform, policy inquiry, or another sustained path whose pursuit requires scarce commitment.

Let $\omega_C : \mathcal{T}(C) \rightarrow \mathbb{R}_{\geq 0}$ be a model-relative orientation-weight function. The weights can summarize salience, perceived worth, expected support, institutional priority, or another explicitly declared orientation relation. They are not assumed to be utilities, probabilities, or objective values. An AI-mediated orientation process M can generate a comparison configuration C^M in which the practically available trajectory family or the orientation weights differ. On a common comparison domain $\mathcal{T}^\cap := \mathcal{T}(C) \cap \mathcal{T}(C^M)$, the orientation reweighting is defined in Equation 18.1.

$$\Delta\omega_M(\tau \mid C) := \omega_{C^M}(\tau) - \omega_C(\tau), \quad \tau \in \mathcal{T}^\cap. \quad (18.1)$$

Equation 18.1 is deliberately modest. A positive value means only that the declared orientation architecture assigns greater weight to trajectory τ after the AI-mediated process. The change can arise because the system made the problem visible, produced a persuasive representation, estimated feasibility, altered perceived difficulty, revealed historical material, changed institutional expectations, or entered a formal ranking procedure. A negative value can arise when a trajectory is deprioritized or made comparatively less salient. Newly generated or removed trajectories require separate support-change analysis because subtraction is undefined when a trajectory lies outside the common domain.

Definition 18.201 (AI-mediated orientation reweighting). *An AI-mediated orientation reweighting is a model-relative change in the salience, priority, support, or perceived worth assigned to research or action trajectories that is attributable, through an explicit dependence account, to AI-mediated generation, representation, ranking, simulation, recommendation, or evaluation.*

The definition connects research orientation to the broader GR treatment of land-

scape deformation while preserving the difference between orientation and power. Reweighting can occur without relational power. A researcher can voluntarily use a model to expand a reading list and change priorities. The power question arises when the orientation mechanism persistently conditions other positions' feasible futures through control, dependence, institutional authority, or another conversion mechanism of the type developed in Chapter 16 and Section 18.3.

AI-mediated orientation can also change support. Let $\text{supp}(\omega_C) := \{\tau \in \mathcal{T}(C) \mid \omega_C(\tau) > 0\}$. If AI generation makes a previously unavailable trajectory practically visible and supportable, the orientation landscape expands. If automated evaluation systematically removes a class of trajectories from institutional consideration, the support can contract. These support changes are potentially more consequential than small reweightings within an unchanged candidate set because they alter which futures are institutionally reachable at all.

Definition 18.202 (Research-and-action orientation profile). *A research-and-action orientation profile is the pair consisting of a practically available trajectory family and a declared orientation-weight structure over that family, together with the historical, relational, institutional, and evaluative conditions required to interpret those weights.*

The profile makes clear why AI-mediated orientation is not merely a matter of personal preference. Search interfaces, grant criteria, publication systems, institutional dashboards, automated recommendation tools, platform visibility, and public funding priorities can all affect which trajectories receive positive support. Once those systems are coupled to allocation, their orientation effects become performative.

Proposition 18.203 (Performative orientation feedback). *When an AI-mediated orientation process changes the allocation of attention, funding, infrastructure, personnel, data collection, or institutional authority, and those allocations subsequently alter the candidate trajectories or orientation criteria used in later rounds, the process forms a performative orientation feedback loop.*

Such feedback can be beneficial. An AI system can reveal an overlooked research area, leading to data collection that makes the area easier to study and yielding a productive new field. Feedback can also narrow inquiry if early machine rankings direct resources toward highly represented topics, which then generate more data and publications and become even easier for later systems to recommend. The direction of the loop therefore requires empirical and historical analysis.

Proposition 18.204 (Orientation-plurality condition). *Where research and action trajectories involve heterogeneous values, uncertain future consequences, or incomplete evidence, resilient AI-mediated orientation is supported by preserving multiple routes of problem formation, criticism, historical reconstruction, relational interpretation, and institutional contestation rather than allowing one generated ranking to become the sole allocator of inquiry.*

Proposition 18.204 identifies plural orientation as a resilience property. Different communities can notice different absences, assign different significance to histories, recognize different affected relations, and preserve different future options. AI can help connect these perspectives, but compression into a single ranking can remove the very disagreement that makes orientation corrigible.

The section has therefore treated AI and research orientation as an economic problem of candidate abundance under scarce judgment. AI can expand problem fields and make difficult questions easier to formulate. Difficulty remains separate from worth. Aesthetic judgment can support exploratory filtering while requiring correction under cheap surface fluency. Historical sensitivity locates problems within paths, exclusions, and prior attempts. Relational sensitivity preserves dependencies and affected positions that generated framings can suppress. Generative judgment assesses possible future-opening effects while remaining distinct from realized value. Orientation responsibility remains with human and institutional relations capable of reason-giving, contestation, revision, and accountability. The reweighting model then shows how AI-mediated generation and recommendation can change the relative support and even the practical availability of research and action trajectories.

These orientation effects become a governance problem when capability asymmetry, dependence, infrastructure control, and institutional authority make some reweightings difficult to contest or reverse. Section 18.13 therefore turns to governance under radical asymmetry, examining capability equalization, counter-power, dependency reduction, access and infrastructure governance, contestability, auditability, reversibility, and protection of human action space.

18.13 Governance under Radical Asymmetry

Sections 18.2–18.12 developed the principal objects that make governance under artificial intelligence distinctive: persistent capability asymmetry, conversion of capability into relational power, changing labor and participation, concentrated ownership of productive intelligence, AI-generated surplus, layered redistribution, human–AI relational economies, epistemic dependence, symbolic abundance, and AI-mediated research orientation. The present section integrates those results at the governance level. Its role is to identify governance functions that remain relevant when capability asymmetry is large, persistent, multidimensional, and only partly reducible through diffusion or training. Its objective is not to prescribe one constitutional model for artificial intelligence. It is to distinguish the mechanisms through which governance can preserve practical alternatives, reduce disabling dependency, constrain conversion of capability into power, maintain contestable access to consequential systems, and protect domains in which human and collective action remain materially possible.

The discussion proceeds through nine dimensions. It begins with the limits of capability equalization and counter-power, then develops dependency reduction, access governance, and infrastructure governance. The section subsequently examines contestability and auditability as governance capacities, revisits reversibility under AI-mediated path dependence, and concludes with protection of human action space. The method is relational and mechanism-specific. Governance is evaluated through the relations it changes: who depends on which system, which alternatives remain practically reachable, who can contest a consequential output, which infrastructures can be switched or repaired, which decisions can be reversed, and which human or collective capacities remain available after repeated AI mediation.

Table 18.13: Governance dimensions under radical capability asymmetry.

Dimension	Primary governance object	Principal analytical question
Capability equalization	Diffusion, education, tools, public capacity, and capability floors	Which asymmetries can be narrowed, and which persistent differences require other governance mechanisms?
Counter-power	Independent capacity to resist, redirect, veto, bargain, or supply alternatives	Where can countervailing power operate effectively, and where does radical asymmetry make symmetric opposition impractical?
Dependency reduction	Substitutability, exit, portability, recovery, retained competence, and alternatives	Which dependencies can be reduced without eliminating productive complementarity?
Access governance	Terms of entry, use, continuity, priority, restriction, and appeal	Who can use consequential AI capabilities, under which conditions, and with which protections against arbitrary exclusion?
Infrastructure governance	Compute, cloud, energy, data, networks, identity, standards, and verification substrates	Which bottlenecks condition the feasible action space of downstream positions, and how are they governed?
Contestability	Practical capacity to challenge classifications, outputs, denials, or decisions	Can affected positions obtain reasons, invoke review, suspend consequences, and reach an authority capable of changing the result?
Auditability	Reconstructible evidence concerning system behavior and governance history	Can consequential operations be examined with sufficient records, authority, access, and competence to support correction?
Reversibility	Rollback, migration, recovery, retained alternatives, and correction capacity	Which commitments remain practically revisable as dependence and complementary investments accumulate?
Human action space	Practically reachable domains of human and collective choice, refusal, learning, judgment, and institution building	Which forms of action remain possible without mandatory mediation by a dominant AI configuration?

Definition 18.205 (Governance profile under radical capability asymmetry). A *governance profile under radical capability asymmetry* records the mechanisms through which a governance architecture addresses persistent capability differences, countervailing capacity, dependency, access, infrastructure, contestation, audit, reversibility, and the preservation of practically reachable human and collective action possibilities within a declared historical and institutional scope.

Definition 18.205 keeps governance multidimensional. A system can provide broad access while remaining difficult to contest. It can support audit while preserving infrastructure dependency. It can redistribute income while leaving exit from a model ecosystem impractical. It can preserve nominal human approval while the practical action space needed for independent judgment has already eroded. Table 18.13 summarizes the nine dimensions developed below.

The rows in Table 18.13 are complementary. Capability equalization can reduce some dependencies. Public infrastructure can create alternatives that strengthen counter-power. Contestability can be weak when auditability is low, while auditability can be institutionally irrelevant when no authority can act on the findings. Reversibility can depend on retained human competence and interoperable infrastructure. Human action space can therefore be understood partly as an emergent prop-

erty of the other governance dimensions rather than as one isolated safeguard.

Proposition 18.206 (Governance-mechanism plurality). *Where capability asymmetry is persistent and multidimensional, governance adequacy cannot be inferred from performance on a single mechanism such as access, redistribution, capability diffusion, or audit. Adequacy requires identifying the specific conversion pathways through which asymmetry becomes dependency or power and matching governance mechanisms to those pathways.*

Proposition 18.206 is the organizing discipline of the section. It also prevents radical asymmetry from becoming a rhetorical label that automatically licenses one institutional response.

18.13.1 Limits of Capability Equalization

Section 18.2 treated capability as a multidimensional profile rather than a scalar measure of intelligence. That result already limits the idea of capability equalization. Education, tool diffusion, open models, public compute, shared data, complementary institutions, and human–AI collaboration can narrow important differences, yet equalization can remain partial because speed, memory, scale, coordination, infrastructure, capital, data access, and organizational integration respond differently to the same intervention. A person can receive access to a high-capability model while lacking the compute, organizational support, verification infrastructure, or legal permissions required to convert that access into comparable productive capacity.

Capability equalization is therefore best treated as one governance mechanism among several. It can reduce the degree to which one position must rely on another for a function. It can enlarge bargaining alternatives. It can preserve professional competence and public-sector capacity. It can also reduce the social cost of exit from a provider. These effects are important even when full parity is unattainable.

Definition 18.207 (Capability-equalization profile). *A capability-equalization governance profile records which capability dimensions a governance arrangement attempts to narrow, the instruments used to do so, the conversion conditions required for practical use, the positions reached by those instruments, and the residual capability asymmetries that remain after implementation.*

The profile can include capability floors rather than pairwise equality. Public education can aim to preserve independent verification competence. Public compute can ensure that research institutions retain capacity to test or adapt models. Interoperability rules can lower switching costs. Open standards can preserve compatibility across providers. Such arrangements can materially reduce dependency even when frontier systems continue to differ greatly in scale or performance.

The residual profile matters because governance can fail if it assumes that a formal opportunity has erased the asymmetry that motivated the intervention. A public model may exist while the private ecosystem retains much greater integration, data, distribution, or maintenance capacity. Training programs can increase skills while the relevant production frontier moves faster than training institutions can update. Equalization should therefore be evaluated dynamically rather than through a one-time snapshot.

Proposition 18.208 (Residual-asymmetry condition). *Where governance narrows some capability dimensions while materially consequential asymmetries persist in complementary dimensions, the remaining asymmetries should continue to be analyzed for dependency and power conversion rather than being treated as resolved by formal capability diffusion.*

The proposition does not imply that equalization is ineffective. It identifies the point at which another governance mechanism becomes necessary. A society can rationally invest in broad capability formation while simultaneously governing access, infrastructure, contestability, and dependency.

18.13.2 Limits of Counter-Power

Power can often be constrained by countervailing power. Workers organize against employers, jurisdictions check one another, professions establish independent standards, competing firms reduce unilateral control, and public institutions can limit private authority. Radical capability asymmetry complicates this architecture because effective counter-power itself requires capability, infrastructure, information, coordination, and time. A position can possess formal rights to oppose a system while lacking the technical or organizational capacity required to exercise those rights effectively.

The relevant issue is therefore the practical construction of counter-power. A regulator that depends on the regulated firm's models, cloud infrastructure, or technical expertise can possess legal authority alongside weak independent capability. Small organizations can negotiate individually with a dominant platform while lacking credible alternatives. Users can leave one service while the entire sector relies on the same upstream compute, identity, or data infrastructure. Counter-power should consequently be evaluated across the dependency stack rather than inferred from the presence of several nominal actors.

Ostrom's work on polycentric governance is relevant because it emphasizes multiple centers of decision making and the possibility of coordination without one monopolistic center (Ostrom 2010). The present use is structural rather than prescriptive. Polycentricity can strengthen comparison, local adaptation, and alternative provision, yet several centers can remain dependent on the same concentrated technical substrate. Institutional plurality and infrastructural plurality therefore need separate diagnosis.

Definition 18.209 (Counter-power capacity). *Counter-power capacity* is the practical capability of a position or coalition to resist, redirect, veto, bargain over, replace, or create credible alternatives to a consequential exercise of relational power, given the information, infrastructure, authority, coordination, and recovery resources available within the relevant historical configuration.

Counter-power need not mirror the dominant capability. A community does not need to train a frontier model to possess meaningful counter-power if it can invoke binding procedural rights, use interoperable alternatives, obtain independent expert review, or collectively govern an essential interface. The mechanism can be legal, infrastructural, organizational, economic, epistemic, or mixed.

Proposition 18.210 (Counter-power non-symmetry). *Effective counter-power does not require capability symmetry with the power-bearing position. It requires at least one consequential pathway through which the countervailing position can alter, constrain, contest, exit, or credibly substitute for the relevant power-conditioned relation.*

This proposition permits governance to search for leverage points other than direct technological parity. It also identifies a limit: where every consequential pathway is controlled by the same capability complex, formal plurality can coexist with weak counter-power.

Proposition 18.211 (Counter-power dependency limit). *Counter-power is weakened when the institutions expected to constrain a power-bearing configuration materially depend on that same configuration for the expertise, infrastructure, data, operational continuity, or decision support required to exercise the constraining function.*

The conclusion is not that dependent governance is impossible. It is that dependence should be included in the governance model rather than hidden behind organizational separation.

18.13.3 Dependency Reduction

Sections 18.3, 18.9, and 18.10 distinguished several forms of dependency: productive dependence, infrastructural dependence, delegation dependence, epistemic dependence, and relational dependence. Governance under radical asymmetry therefore needs a more precise objective than eliminating dependence. Economic systems are built from interdependence. Hospitals depend on power grids, firms depend on logistics, researchers depend on archives, and people depend on one another for care and knowledge. The governance concern arises when dependence becomes disabling, non-contestable, difficult to exit, or readily convertible into persistent relational power.

Dependency reduction can operate through several levers. Substitutability creates credible alternatives. Portability allows records, workflows, and accumulated assets to move. Interoperability permits other systems to connect. Retained competence prevents total loss of independent capability. Redundancy preserves operation when one provider fails. Public or commons provision can supply fallback capacity. Contractual and legal protections can limit unilateral changes. Recovery infrastructure can preserve continuity after exit or failure.

Definition 18.212 (AI dependency-reduction profile). *An AI dependency-reduction profile records, for a specified human–AI or institution–AI relation, the practical substitutability of the AI-mediated function, the feasibility of exit and migration, portability of relevant records and assets, retained human or organizational competence, recovery capacity, alternative providers or procedures, verification independence, and the historical conditions under which these capacities can be maintained.*

The profile is dynamic. A relation that is initially easy to exit can become difficult to leave after data formats, organizational routines, professional skills, workflows, or complementary investments are reorganized around one system. Dependency reduction must therefore include maintenance of alternatives, not merely their initial existence.

Proposition 18.213 (Dependency-reduction power condition). *Where a capability asymmetry becomes power-relevant principally through dependency, governance that materially improves substitutability, exit, portability, retained competence, recovery, or alternative provision can reduce the conversion of that asymmetry into relational power even when the underlying capability difference remains large.*

This proposition is one of the central implications of the chapter. It shifts some governance attention from eliminating capability differences to changing the relations through which those differences become consequential.

18.13.4 Access Governance

Section 18.6 distinguished model ownership, compute ownership, data control, platform control, infrastructure control, and access rights. Access governance concerns the terms through which those underlying positions are converted into practical use. It includes admission, pricing, rate limits, identity requirements, permissible uses, service continuity, priority during scarcity, geographic restrictions, interface design, API conditions, model versions, termination, appeals, and the allocation of exceptional access for research, public administration, or essential services.

Access has both enabling and protective functions. Broad access can diffuse productive capacity, reduce asymmetry, and support innovation. Restrictions can also protect privacy, security, safety, or scarce infrastructure. The governance question is therefore not maximal access in the abstract. It is whether the access architecture is justified, predictable, contestable, and compatible with the capability and participation functions the institution is expected to support.

Definition 18.214 (Governed AI access profile). *A governed AI access profile specifies the eligibility conditions, practical usability, price or resource requirements, duration and continuity expectations, usage constraints, prioritization rules, modification rights, portability conditions, termination procedures, review mechanisms, and affected positions associated with access to a consequential AI capability or service.*

Formal availability and effective access remain distinct. A model can be technically public while high compute requirements make meaningful use inaccessible. An API can be available while rate limits prevent institutional-scale operation. A public service can be nominally universal while language, disability, identity, connectivity, or payment requirements exclude practical use. Access governance should therefore preserve the conversion analysis developed in Section 18.8.

Proposition 18.215 (Access–control non-equivalence). *Broad access to an AI capability does not by itself distribute control over model evolution, infrastructure, service continuity, usage rules, data retention, or downstream decision authority. Access governance and control governance should therefore remain analytically distinct.*

The distinction prevents a public-facing interface from being treated as evidence of distributed productive intelligence. It also supports targeted governance: one problem may require broader access, another continuity guarantees, another portability, and another limits on unilateral rule change.

18.13.5 Infrastructure Governance

AI capability is materially dependent on infrastructures that extend beyond the model itself. Compute hardware, data centers, cloud services, energy, cooling, network connectivity, identity systems, payments, cybersecurity, data pipelines, standards, logging systems, and verification tools can each become bottlenecks. Section 18.6 treated control over such infrastructures as an ownership and power question. The present subsection asks how those infrastructures can be governed when their failure, concentration, or exclusion materially conditions downstream action.

Infrastructure governance has at least four functions. The first is continuity: essential users may require predictable service and recovery capacity. The second is plurality: several providers or interoperable architectures can reduce single-point dependency. The third is public-interest access: research, education, public administration, or socially necessary services can require capacity that market allocation alone does not guarantee. The fourth is accountability: infrastructure operators can shape downstream possibilities through technical rules that are difficult for users to observe or contest.

Definition 18.216 (AI infrastructure-governance profile). An *AI infrastructure-governance profile* records the ownership, control, access, continuity, interoperability, redundancy, security, maintenance, public-interest obligations, failure recovery, environmental dependencies, and review mechanisms associated with the infrastructural layers required to realize AI capability in a specified field.

Infrastructure governance can be public, private, cooperative, commons-based, polycentric, or hybrid. The relevant criterion is functional rather than categorical: which arrangements preserve continuity, alternatives, accountability, and justified access under the dependency structure of the field.

Proposition 18.217 (Bottleneck-governance condition). *Where a small set of infrastructural bottlenecks materially determines the practical availability of otherwise distributed AI capabilities, governance of those bottlenecks can be more consequential for dependency and power than formal distribution of model access alone.*

The proposition explains why open models can coexist with concentrated productive intelligence. It also creates an interface with public-infrastructure and commons analysis later in the book.

18.13.6 Contestability

Chapter 16 developed participation and contestability as general governance objects, while Sections 18.10–18.12 showed how AI-mediated knowledge, representation, and orientation can influence consequential decisions. Under radical asymmetry, contestability matters because affected positions may be unable to reproduce the capability used to generate a classification, recommendation, risk score, research priority, eligibility decision, or service denial. Governance must therefore distinguish the capacity to reproduce the system from the capacity to challenge its consequential use.

Effective contestability requires more than a complaint channel. A person needs to know that a consequential determination occurred, understand enough of its ba-

sis to identify a ground of challenge, reach a reviewing authority, present relevant evidence, obtain suspension or mitigation where delay would make review meaningless, and receive a reasoned response that can alter the outcome. Different domains can require different levels of explanation, evidence disclosure, confidentiality, and review.

Definition 18.218 (AI-governance contestability). *AI-governance contestability* is the practical capacity of an affected position to identify a consequential AI-mediated determination, obtain sufficient information to formulate a challenge, submit relevant evidence or reasons, reach an authority with power to review and alter the determination or its effects, and receive a traceable response within a time horizon that preserves meaningful remedy.

Contestability can be individual or collective. A professional association can challenge a system-wide classification rule. A municipality can contest an infrastructure provider's access condition. A research community can challenge automated funding criteria. Collective contestation can be especially important where individual cases are weak evidence of a systematic effect.

Proposition 18.219 (Consequential-contestability condition). *A nominal review process provides weak contestability when the reviewing body lacks practical authority, relevant evidence, independent expertise, time, or capacity to alter the consequential relation under challenge.*

This condition mirrors the distinction between formal and effective participation developed earlier in the book. It also links contestability to auditability, because a challenge can require records that ordinary users cannot generate themselves.

18.13.7 Auditability

Auditability concerns the reconstructibility of consequential system behavior and governance history. It is related to transparency but is not identical with it. Publishing code, model cards, or aggregate metrics can improve visibility while leaving a specific decision path, version history, data transformation, access change, or institutional authorization difficult to reconstruct. Conversely, a system can remain partly opaque in technical detail while preserving strong audit records concerning inputs, outputs, decisions, overrides, failures, and governance procedures.

Kroll and colleagues emphasize the importance of accountability mechanisms that extend beyond direct source-code transparency (Kroll et al. 2017). The same principle applies here. Under radical capability asymmetry, the audit question is whether an authorized and sufficiently independent process can reconstruct the evidence needed to evaluate a consequential claim, system behavior, or governance failure.

Definition 18.220 (AI governance auditability). *AI governance auditability* is the degree to which a consequential AI-mediated operation can be reconstructed and evaluated through preserved records, version information, provenance, decision logs, authorization histories, relevant inputs and outputs, performance evidence, override records, and access to the technical and institutional expertise required for a declared audit purpose.

Auditability can fail through absence of records, inaccessible records, rapidly

changing systems, weak version control, proprietary barriers, missing provenance, insufficient expertise, or lack of legal authority. Retention itself can create privacy and security burdens. Governance should therefore specify which records are necessary for which audit purpose and how long they should be preserved.

Proposition 18.221 (Auditability–accountability non-equivalence). *Auditability can supply evidence for accountability, correction, and contestation, but it does not by itself determine responsibility, remedy, legitimacy, or institutional response. An auditable system remains weakly governed when no position is authorized or capable of acting on the audit findings.*

This proposition keeps audit inside the wider governance architecture. Audit evidence becomes consequential only through institutions that can revise rules, repair harm, change access, impose obligations, or otherwise alter the relation under review.

18.13.8 Reversibility

Chapter 16 treated reversibility as a changing governance capacity rather than a binary property. AI intensifies this problem because deployment can reorganize workflows, skills, data, institutions, infrastructure, expectations, and professional roles. A model can be removed while the organization remains unable to return to the earlier mode of operation. Formal revocability of an AI system is therefore weaker than practical reversibility of the institutional transformation it helped generate.

Reversibility under radical asymmetry has several components. Technical rollback concerns the ability to suspend or replace a system. Data reversibility concerns recovery, portability, and deletion. Organizational reversibility concerns the ability to restore or redesign workflows. Capability reversibility concerns whether human or alternative institutional competence remains available. Contractual reversibility concerns exit from provider obligations. Relational reversibility concerns whether dependencies, expectations, or role structures can still be changed without disproportionate harm.

Definition 18.222 (AI governance reversibility reserve). *An AI governance reversibility reserve is the retained collection of technical alternatives, interoperable data and records, human and organizational competence, contractual exit rights, independent infrastructure, financial resources, authority, time, and recovery pathways required to revise, suspend, replace, or substantially redirect an AI-mediated arrangement before the relevant option space closes.*

The reserve can decay. Human expertise can atrophy. Alternative suppliers can exit the market. Data can migrate into proprietary formats. Public institutions can redesign themselves around one system. Complementary investment can become sunk. Governance should therefore monitor the conditions of rollback while adoption proceeds, as Section 16.15 required for near-critical interventions and Section 16.20 generalized for adaptive governance.

Proposition 18.223 (AI reversibility-decay condition). *Where repeated AI adoption reduces alternative provision, retained competence, interoperability, exit rights, or recovery resources, formal authority to discontinue the system becomes a progressively*

weaker indicator of practical reversibility.

Reversibility does not imply that every decision should remain easy to undo. Stable rights, safety protections, and long-horizon infrastructure can require commitment. The governance task is to identify which dimensions require credible durability and which require preserved correction pathways under uncertainty.

18.13.9 Protection of Human Action Space

The preceding governance dimensions converge on a broader object: human action space. The term does not mean preserving a domain in which humans remain technologically superior. It refers to preserving practically reachable possibilities through which persons and human-governed collectives can form purposes, learn, deliberate, refuse, choose alternatives, create institutions, maintain care relations, contest authority, develop knowledge, and initiate actions whose feasibility is not wholly conditional on one dominant AI-mediated configuration.

Sen's capability approach provides an important neighboring intuition: evaluation should concern substantive opportunities as well as resources or formal rights (Sen 1999). GRE's use is narrower and historically relational. The relevant action space is generated through institutions, infrastructures, skills, records, rights, social relations, and technological interfaces. It can expand or contract as those relations change. Formal permission to act has limited value when the capabilities or infrastructures required for action have disappeared.

Definition 18.224 (Human action space under AI mediation). The *human action space under AI mediation* is the model-relative family of practically reachable actions, relations, institutional formations, learning trajectories, refusal options, interpretive practices, collective organizations, and alternative technological arrangements that persons and human-governed collectives can initiate or sustain without being obligatorily routed through a specified dominant AI-mediated dependency.

The definition is relational rather than species-essentialist. It does not claim that every valuable human action must exclude AI. Human action space can include intensive AI collaboration. The relevant condition is preservation of meaningful alternatives and human-governed capacities sufficient to choose, contest, redesign, or refuse particular forms of mediation.

Protection of action space can therefore include public education, independent research capacity, interoperable systems, human-accessible procedures, non-digital fallbacks for essential services, professional competence, local institutional authority, public or commons infrastructure, collective organization, and protected domains of deliberation. The appropriate mix depends on the function and the cost of dependence.

Proposition 18.225 (Action-space protection condition). *Under radical capability asymmetry, governance protects human action space when it preserves materially usable alternatives through which persons or human-governed collectives can continue consequential learning, judgment, refusal, coordination, institution building, and action even if a dominant AI-mediated relation is unavailable, contested, or intentionally declined.*

Action-space protection is stronger than nominal human oversight. A human reviewer whose judgment depends completely on the same system being reviewed may occupy a formal role without possessing an independent action space. A public institution that can legally switch vendors but lacks data portability, staff competence, or alternative infrastructure has weak practical choice. The protected object is therefore the future capability to act differently.

Proposition 18.226 (Generative action-space condition). *A governance arrangement has a stronger generative action-space property when it preserves not only currently available alternatives but also the capacities, institutions, infrastructures, records, and participation pathways through which new alternatives can be formed after future conditions change.*

This proposition connects action-space protection to GRE's wider concern with generativity. A fixed fallback procedure can preserve one alternative today while offering little capacity to respond to unforeseen changes. A resilient governance architecture maintains the means of generating alternatives: people able to learn, institutions able to revise, infrastructures able to interoperate, communities able to organize, and records sufficient to reconstruct why earlier arrangements existed.

Governance under radical asymmetry therefore does not require a single strategy of equalization, prohibition, decentralization, or control. Capability equalization can narrow selected gaps. Counter-power can constrain power without reproducing the same capabilities. Dependency reduction can change the mechanism through which asymmetry becomes power. Access and infrastructure governance can preserve practical alternatives and public-interest capacity. Contestability and auditability can make consequential uses challengeable and reconstructible. Reversibility can keep correction paths open as institutional dependence deepens. Protection of human action space then supplies a broader generative criterion: whether humans and human-governed collectives retain practical capacity to form, contest, and create future arrangements rather than merely adapt to one increasingly entrenched technological field.

The analysis also identifies a limit of governance framed only as protection. Preserving action space does not by itself ensure that people can participate meaningfully in knowledge, decisions, institutions, care, community, or culture. Section 18.14 therefore turns from protective governance to *generative participation under AI*, examining the institutional conditions through which human participation can remain consequential even where comparative productive necessity declines.

18.14 Generative Participation under AI

Sections 18.4–18.13 progressively separated employment, material distribution, existential participation, productive-intelligence ownership, human–AI relational organization, epistemic dependence, research orientation, and governance under radical capability asymmetry. The present section develops a stronger participatory object. Its role is to ask whether persons and human-governed collectives remain able to enter the processes through which future knowledge, decisions, institutions, care relations, communities, cultural forms, and alternatives are generated. Its objective is

therefore broader than preserving access to goods or services and narrower than providing a complete political or moral theory of participation. The analysis proceeds across eight domains: knowledge, decision, institutions, care, community, culture, participation beyond productive necessity, and protection against generative foreclosure. Throughout the section, participation is treated as historically and institutionally organized. Artificial systems can mediate or contribute to these processes without the analysis presupposing artificial subjecthood, a question reserved for Section 18.15.

A distinction among several participatory statuses is useful at the outset. A person can be *present* in a system without influencing it, can possess *access* without practical capability to use it, can be *consulted* without affecting the decision rule, can *consume* knowledge without participating in its production or criticism, and can receive material provision without participating in the institutions that organize provision. Generative participation concerns a further relation: the ability to contribute to the formation, revision, maintenance, interpretation, or replacement of structures that condition later possibilities.

Definition 18.227 (Generative participation under AI). *Generative participation under AI* is the practical capacity of a person or human-governed collective to enter, influence, sustain, revise, contest, or initiate AI-mediated and AI-adjacent processes through which later knowledge, decisions, institutions, relations, cultural forms, capabilities, or feasible alternatives are produced.

The definition is deliberately plural. Participation can be direct, representative, professional, community-based, institutional, or infrastructural. It can occur with intensive AI assistance. The relevant condition is consequential participation in the generation of later relational possibilities rather than preservation of a technologically isolated human domain.

Proposition 18.228 (Participation–presence non-equivalence). *Presence, access, consultation, or receipt of benefits does not by itself establish generative participation. A stronger participation claim requires at least one practically consequential pathway through which the participating position can alter, sustain, contest, reinterpret, or initiate a process that conditions later possibilities.*

Table 18.14 summarizes the eight participatory domains developed below. The dimensions can reinforce one another without being reducible to one common scale. Knowledge participation can support decision participation; institutional participation can protect care or cultural participation; community participation can generate new knowledge and institutions. Their interaction is historically contingent.

18.14.1 Participation in Knowledge

Chapter 17 treated knowledge as an economic object embedded in attention, institutions, infrastructure, preservation, justice, and relational participation. Artificial intelligence intensifies the distinction between access to knowledge products and participation in knowing. A person can receive answers of high apparent quality while contributing little to question formation, evidence selection, verification, interpretation, criticism, preservation, or the production of later research directions. Such access can be valuable, but its economic consequences differ from those of sustained

Table 18.14: Dimensions of generative participation under AI.

Domain	Participatory object	Generative consequence	Characteristic constraint
Knowledge	Questions, evidence, interpretation, criticism, preservation	Later inquiry and epistemic capability	Passive consumption or unverifiable mediation
Decision	Problem framing, criteria, deliberation, revision, appeal	Later choices, priorities, and admissible actions	Participation after the consequential frame is fixed
Institutions	Rules, roles, procedures, infrastructures, governance	Reproduction and redesign of collective capacity	Fixed institutional interfaces or inaccessible rule formation
Care	Attention, responsibility, responsiveness, continuity	Maintenance and development of persons and relations	Task substitution that removes reciprocal or accountable participation
Community	Shared projects, mutual support, local organization	Collective capability and new relational possibilities	Platform dependence, weak collective control, or fragmented association
Culture	Creation, interpretation, transmission, criticism	Symbolic repertoires and later meaning formation	Synthetic abundance with concentrated visibility or cultural production channels
Post-necessity participation	Learning, making, stewardship, inquiry, care, association	Contribution beyond labor-market demand	Social membership tied narrowly to employment or productivity
Foreclosure protection	Alternative-forming capacities and institutions	Future creation of options and institutional forms	Irreversible dependency, deskilling, enclosure, or loss of generative pathways

participation in the epistemic process.

Knowledge participation under AI can occur at several stages. Participants can identify problems that automated systems do not make salient. They can contribute observations or situated knowledge. They can inspect provenance, test outputs, compare interpretations, formulate counterexamples, maintain records, translate across knowledge systems, and decide which uncertainties deserve further inquiry. They can also participate in the governance of datasets, archives, model-mediated research infrastructure, and institutional standards that shape what becomes epistemically visible.

Longino's social account of scientific knowledge emphasizes criticism and community interaction in the production of knowledge (Longino 1990). Situated-learning traditions likewise emphasize participation in practice rather than the transfer of decontextualized information alone (Lave and Wenger 1991; Wenger 1998). The present use is economic and institutional: if AI changes the cost of producing candidate an-

swers, the capacity to participate in criticism, verification, question formation, and knowledge maintenance can become a more consequential scarce capability.

Definition 18.229 (Epistemic generative participation). *Epistemic generative participation* is practical participation in one or more processes through which questions, evidence, interpretations, warrants, critiques, records, or research directions are produced or revised in ways that condition later inquiry.

The definition does not require every participant to reproduce the technical operations of an AI system. A patient can contribute experiential evidence without implementing a medical model. A local community can identify missing environmental variables without reproducing a remote-sensing pipeline. A student can challenge an interpretation without training a language model. The participatory requirement concerns a consequential interface through which the contribution can enter the epistemic process.

Proposition 18.230 (Knowledge-participation condition). *AI-mediated knowledge access supports stronger epistemic generative participation when affected positions retain practical pathways to formulate questions, contribute evidence, inspect or challenge relevant claims, preserve alternative interpretations, and influence the continuation of inquiry.*

This condition connects participation to the epistemic-agency reserve developed in Section 18.10. The reserve concerns retained human and institutional capability; generative participation concerns whether that capability has consequential pathways into ongoing knowledge formation. A society can possess competent experts whose work is systematically excluded from AI-mediated decision systems, or open interfaces through which participants can submit material that no institution is required to consider. Capability and uptake therefore remain distinct.

18.14.2 Participation in Decision

Decision participation concerns the formation of consequential choices rather than the mere notification of outcomes. AI-mediated decision systems can reorganize this process by generating recommendations, ranking options, setting default categories, estimating risks, allocating attention, or preselecting the questions that decision makers encounter. Participation that occurs only after these structures are fixed can remain procedurally visible while having limited influence over the generative conditions of the decision.

A fuller architecture distinguishes participation in problem definition, criterion formation, evidence interpretation, option generation, deliberation, authorization, implementation, monitoring, revision, and appeal. Different institutions can distribute these roles differently. Technical experts may define feasible options, affected communities may supply local knowledge, elected or appointed authorities may bear formal responsibility, and AI systems may generate analysis. The relevant GRE question is which positions can change the decision-generating process and under what conditions.

Definition 18.231 (Generative decision participation). *Generative decision participation* is the practical capacity of an affected or authorized position to influence the

formation of a consequential decision by contributing to at least one of its generative components, including problem framing, admissible criteria, evidence, option formation, deliberation, authorization, revision, or remedy.

The definition separates participation from universal co-decision. Some decisions require specialized competence, confidentiality, speed, or delegated authority. Generative participation can therefore be differentiated by role. What matters is whether the allocation of roles leaves meaningful pathways for relevant knowledge, interests, reasons, and contestation to alter the process where they are substantively pertinent.

Proposition 18.232 (Decision-framing participation). *Where an AI-mediated system fixes the problem representation, admissible evidence, evaluative criteria, or option set before affected positions can participate, later consultation can leave the principal generative structure of the decision unchanged even when the consultation itself is procedurally genuine.*

This proposition is not an argument that every decision frame should remain permanently open. Closure is necessary for action. The analytical obligation is to identify where closure occurs, who can participate before and after it, and which revision pathways remain available when the frame proves inadequate. Section 18.13 developed contestability and reversibility for this reason. Generative decision participation adds the positive dimension: people should not be positioned only as objects of review after AI-mediated framing has already organized the field of possible action.

18.14.3 Participation in Institutions

Institutions preserve and reproduce economic possibilities across time. They define membership, standing, ownership, procedural access, professional roles, evidence requirements, allocation rules, and infrastructures. AI can enter institutions as a tool used within existing procedures, yet sustained adoption can also alter the procedures themselves. Automated triage can become an eligibility architecture; model-mediated assessment can reshape professional roles; platform interfaces can become de facto administrative infrastructure; and technical standards can redefine which participants are legible to the institution.

Participation in institutions therefore extends beyond using institutional services. It concerns the capacity to take part in rule formation, institutional maintenance, representation, evaluation, and redesign. Ostrom's analysis of commons governance illustrates how participants can be involved in rule systems governing shared resources (Ostrom 1990). GRE generalizes the structural point without treating one institutional form as universally appropriate: institutions can differ in who participates, which rules are revisable, how expertise is incorporated, and how affected positions gain standing.

Definition 18.233 (Institutional generative participation). *Institutional generative participation* is the practical capacity of members, affected positions, or authorized representatives to contribute to the formation, maintenance, evaluation, contestation, or redesign of institutional rules, roles, procedures, infrastructures, or boundaries that condition later participation.

Institutional participation can be direct or mediated. Workers can elect represen-

tatives; professional bodies can establish standards; local communities can participate in planning; independent auditors can represent public accountability functions; public institutions can govern shared infrastructure on behalf of broader constituencies. The form of representation requires separate normative evaluation, yet the existence of an institutional route is analytically distinct from the outcome it produces.

Proposition 18.234 (Institution-making capacity). *A participation architecture is more generative when participants retain practical capacity not only to operate within existing institutional rules but also to propose, test, revise, and organize alternative institutional arrangements when existing rules cease to support relevant purposes or affected positions.*

The proposition connects institutional participation to human action space. A population can retain access to services while losing capacity to shape the institutions through which those services are delivered. If essential governance is progressively embedded in opaque vendor workflows, proprietary standards, or non-portable infrastructure, formal public authority can coexist with declining institution-making capacity. Protecting participation therefore includes preserving institutional competence, records, legal authority, organizational memory, and alternative infrastructures through which redesign remains feasible.

18.14.4 Participation in Care

Section 18.4 distinguished care-related tasks from the broader care relation. The present subsection develops the participatory consequence. Care recipients, caregivers, families, professionals, communities, and public institutions can all participate in defining needs, interpreting changes, allocating attention, maintaining continuity, and deciding how assistance is organized. AI can support these relations through monitoring, communication, scheduling, translation, documentation, decision support, and robotic assistance. It can also narrow participation if care is reorganized around standardized classifications or remote systems that leave recipients and frontline caregivers with weak capacity to revise the care process.

Feminist economics has shown that care involves maintenance, responsibility, and relational labor that extend across paid and unpaid domains (Folbre 2001; England 2005). The generative issue is not the preservation of every existing care task. It is whether care arrangements continue to support reciprocal interpretation, responsibility, development, and the capacity of involved persons to shape the relation where their participation is relevant.

Definition 18.235 (Generative care participation). *Generative care participation is practical involvement in the interpretation, provision, revision, or governance of care relations in ways that can influence the later capabilities, continuity, trust, responsibility, or relational conditions of the persons and collectives involved.*

The definition includes the participation of care recipients where their capacities and circumstances permit, while allowing representation and supported decision arrangements where direct participation is limited. It also includes caregiver participation in organizational design. A system that asks frontline caregivers to implement AI-generated protocols while excluding their observations from protocol revision can increase procedural standardization while weakening generative participation.

Proposition 18.236 (Care-participation preservation). *AI-mediated care preserves a stronger participatory structure when technical substitution reduces burdens or extends capability while retaining consequential pathways for recipients, caregivers, and accountable institutions to interpret needs, revise arrangements, and assume or contest responsibility for later care trajectories.*

This formulation leaves open substantial technical substitution. Some care processes can become safer or more accessible when automation is extensive. The analytical concern is whether the resulting relation preserves appropriate human and institutional participation in the generative functions that remain consequential for care.

18.14.5 Participation in Community

Community participation concerns collective relations that are neither reducible to markets nor exhausted by formal government. Neighborhood associations, mutual-aid networks, religious or cultural organizations, clubs, cooperatives, open-source communities, informal support networks, and local public initiatives can generate resources, knowledge, belonging, care, norms, and practical alternatives. Their economic significance lies partly in the collective capacities they sustain and the pathways through which participants can organize responses to changing conditions.

AI can lower coordination costs, improve translation, support administration, make specialized expertise accessible, and help small communities produce communication or analysis that previously required larger organizations. The same mediation can produce platform dependence, centralized visibility rules, automated moderation effects, surveillance, or homogenized organizational templates. Community participation therefore depends on more than communication volume.

Definition 18.237 (Community generative participation). *Community generative participation* is the practical capacity of persons to contribute to collectively organized relations through which a community can identify concerns, coordinate resources, maintain shared practices, provide mutual support, create local institutions, or generate responses to changing conditions.

Community participation is heterogeneous. Some members contribute time, others knowledge, resources, care, representation, infrastructure, cultural memory, or occasional support. Equal intensity of contribution is not required. The relevant issue is whether the collective relation maintains accessible pathways through which members can contribute and whether the resulting collective capacity remains sufficiently governable by the community rather than becoming wholly dependent on an external AI-mediated infrastructure.

Proposition 18.238 (Community-capability condition). *AI-mediated coordination strengthens community generative participation when it enlarges collective capability while preserving practical community influence over membership, communication, records, shared resources, organizational rules, and the formation of local alternatives.*

The proposition connects community participation to distributed ownership and infrastructure governance. A community can use a proprietary platform productively while retaining substantial collective capacity, or it can become unable to or-

ganize outside that platform. The difference is relational and historical rather than inferable from the software license alone.

18.14.6 Participation in Culture

Culture is particularly exposed to the effects of symbolic abundance developed in Section 18.11. Synthetic text, images, music, video, translation, and stylistic transformation can dramatically enlarge the volume of available cultural material. Greater volume, however, does not establish broader cultural participation. Participation concerns the capacity to create, interpret, transmit, contest, preserve, recombine, and establish new cultural forms whose meanings can become consequential within communities and institutions.

Dewey's account of art as experience provides a neighboring intuition that aesthetic life is situated in relations between experience, expression, and environment (Dewey 1934). The present economic use is narrower. Cultural production requires time, tools, education, visibility, archives, venues, audiences, rights, recognition, and communities of interpretation. AI can alter each of these conditions. It can lower production barriers while simultaneously concentrating distribution, recommendation, or attention.

Definition 18.239 (Cultural generative participation). *Cultural generative participation* is the practical capacity to create, interpret, transmit, preserve, contest, or recombine symbolic and aesthetic forms in ways that can contribute to later cultural repertoires, shared meanings, practices, identities, or institutions.

This definition does not reserve cultural generation to professional creators. Everyday language, ritual, local memory, fan practices, craft, archives, education, performance, and community interpretation can all participate. Nor does it treat AI-generated cultural material as categorically external to culture. Such material can enter cultural relations through selection, interpretation, circulation, modification, and institutional use. The question is how the generative roles and opportunities are distributed.

Proposition 18.240 (Cultural-access and participation non-equivalence). *An increase in the availability of cultural artifacts does not by itself establish an increase in cultural generative participation. Participation also depends on practical capability to create or reinterpret material, pathways to audiences and institutions, preservation and attribution conditions, and the possibility of influencing later cultural formation.*

The distinction is important where recommendation systems concentrate attention. Production can become abundant while cultural visibility remains scarce. A small number of distribution systems can therefore mediate which cultural trajectories receive enough attention, preservation, and institutional recognition to influence later repertoires. The problem links cultural participation to the attention economy of Chapter 17 and to infrastructure governance in Section 18.13.

18.14.7 Participation beyond Productive Necessity

Section 18.4 separated labor-market demand from human contribution, and Section 18.5 developed participation beyond employment. The present subsection asks

a more generative question. If artificial productive capacity reduces the amount of human labor economically necessary for material production, which institutional arrangements allow people to remain participants in the generation of knowledge, institutions, care, community, culture, and future possibilities?

A labor-scarce economy can organize non-employed persons in very different ways. Material transfers can support consumption while leaving participation dependent on private wealth or voluntary opportunity. Public services can provide education and care while keeping recipients primarily in a client role. Commons, civic institutions, research networks, community organizations, cultural institutions, local governance, open infrastructures, and educational systems can instead create organized pathways through which people contribute to collective generation without needing their contribution to be justified by labor scarcity or market profitability.

Definition 18.241 (Post-necessity generative participation). *Post-necessity generative participation* is participation in socially or economically consequential knowledge, care, institutional, community, cultural, ecological, educational, or exploratory processes whose legitimacy and practical accessibility do not depend primarily on the participant's labor being scarce or commercially necessary.

The term *post-necessity* is conditional and local. It does not claim that an economy has eliminated scarcity or labor. It identifies domains in which a person's participation can remain consequential even when their labor is no longer required for a particular productive task or income relation.

Arendt's distinction among labor, work, and action is relevant as a neighboring philosophical resource because it resists reducing human activity to one productive category (Arendt 1958). GRE does not import that tripartite ontology directly. It uses the broader insight to keep economic participation analytically open when employment no longer bundles contribution, social position, and access as tightly as before.

Proposition 18.242 (Productive-necessity non-equivalence). *Declining productive necessity for a person's labor does not entail declining capacity for generative participation. The two coincide only where institutions make participation contingent on market demand, employment status, or another scarcity-based admission rule.*

This proposition changes the design problem. An AI-rich economy need not ask only how to compensate persons whose labor is displaced. It can also ask which participatory infrastructures make learning, inquiry, care, stewardship, culture, community organization, and institution building practically available as durable parts of economic life. Income security remains relevant because participation requires time and material support. Yet the architecture of opportunities cannot be inferred from the transfer alone.

Proposition 18.243 (Participation-infrastructure condition). *Post-necessity generative participation is more practically available when material security is coupled with institutions, infrastructures, rights, spaces, communities, educational pathways, and governance arrangements through which contributions can enter consequential collective processes.*

The condition connects Sections 18.8 and 18.14. Redistribution can secure the material basis of participation; participatory infrastructure determines whether sup-

ported persons can convert that basis into consequential relational activity.

18.14.8 Protection from Generative Foreclosure

The preceding subsections share one temporal concern. Participation can be lost before a present service or entitlement disappears. A community can retain access to an AI platform while losing independent organizational infrastructure. A profession can retain formal authority while losing the skills and records needed to revise its practices. Citizens can retain voting rights while consequential problem framing migrates into inaccessible technical systems. Learners can receive high-quality assistance while the institutions that cultivate independent inquiry atrophy. These changes can close future pathways through which alternatives would otherwise be generated.

GRE requires a term for this stronger temporal loss. *Foreclosure* here does not mean that one present option is unavailable. It concerns the removal or severe degradation of the generative conditions through which a class of future options, institutions, interpretations, or practices could later be produced.

Definition 18.244 (Generative foreclosure). *Generative foreclosure* is a historically produced condition in which an AI-mediated or AI-adjacent configuration materially weakens or removes the capabilities, institutions, infrastructures, records, rights, relations, or participation pathways required to generate a relevant family of future alternatives, even when some current outputs or services remain available.

Generative foreclosure can arise through several mechanisms. Deskilling can remove independent competence. Infrastructure concentration can eliminate alternative deployment pathways. Data enclosure can prevent later reconstruction. Institutional outsourcing can dissolve internal capacity. Automated standardization can narrow recognized categories. Attention concentration can suppress cultural or epistemic alternatives. Dependency can make exit formally possible while rendering replacement practically infeasible. The mechanisms can combine.

The concept is stronger than path dependence. Every historical system inherits constraints from earlier decisions. Foreclosure concerns a degree and type of path dependence in which alternative-forming capacity itself is impaired. It is also distinct from irreversible harm. Some foreclosures can be reversed through costly rebuilding; others can persist long enough to make restoration historically difficult even when technical replacement becomes possible.

Proposition 18.245 (Generative-foreclosure condition). *A stronger claim of generative foreclosure is warranted when an AI-mediated transition does more than select among current options and instead degrades the practical mechanisms through which affected positions could later formulate, organize, test, finance, preserve, or institutionalize relevant alternatives.*

This condition links participation to the generative action-space criterion in Section 18.13. Action-space protection preserves reachable alternatives and the means of generating new ones. Generative-participation analysis asks who can exercise those means and through which domains. The two are complementary: an alternative can exist institutionally while remaining inaccessible to most participants, and broad par-

ticipation can remain shallow where the system has lost capacity to generate substantially different alternatives.

Definition 18.246 (Generative-participation reserve). A *generative-participation reserve* is the retained ensemble of capabilities, rights, institutional roles, infrastructures, records, spaces, communities, educational pathways, and governance interfaces through which persons and human-governed collectives can continue to enter future-forming processes after technological or institutional conditions change.

The reserve is not a stock that can be preserved unchanged. Its components require maintenance and renewal. Educational systems must update capabilities; archives need migration; civic and community institutions need members and resources; professional organizations need independent expertise; public and commons infrastructures need technical maintenance; cultural institutions need spaces for new interpretation. A reserve can therefore remain nominally present while losing practical generative capacity.

Proposition 18.247 (Anti-foreclosure generativity). A *participation architecture* has a stronger anti-foreclosure property when it preserves both current pathways of consequential participation and the capacities through which participants can create, revise, or institutionalize new pathways under future conditions that cannot be fully specified in advance.

The proposition supplies the section's long-horizon criterion. Generative participation under AI is not secured merely by assigning humans a residual role inside a fixed technological order. It is secured more strongly when people and human-governed collectives retain practical capacity to reshape the order itself: to generate knowledge, contest decisions, redesign institutions, reorganize care, form communities, create culture, and construct new forms of participation when earlier arrangements become inadequate.

The section therefore extends the governance architecture of Section 18.13 from protected possibility to consequential participation. Human action space identifies the alternatives that remain practically reachable; generative participation identifies the relations through which people and collectives can help form later possibilities within that space. Protection from generative foreclosure adds the intertemporal condition that these participatory pathways should remain capable of producing alternatives that do not yet exist. The resulting architecture does not assume that humans remain uniquely capable in every domain. It asks whether the economic order continues to contain practical, consequential, and revisable pathways through which human and human-governed collective participation can remain part of the generation of future relational worlds.

The next section turns to a different source of heterogeneity. Participation cannot be governed adequately if every participant is assumed to instantiate one common subject type or one universal value structure. Section 18.15 therefore examines human subjects, artificial agents, collective subjects, non-human subjects, and heterogeneous value structures within the same AI-mediated economic field.

18.15 Heterogeneous Subjects and Value Structures

Section 18.14 developed generative participation as the practical capacity to enter processes through which later knowledge, decisions, institutions, relations, cultural forms, capabilities, and alternatives are produced. The present section specifies a prior condition for governing such participation: participants in an AI-mediated economy need not instantiate one common form of subjecthood, and the values relevant to their participation need not be representable within one common evaluative structure. Its role in Chapter 18 is therefore to connect the plural account of economic subjecthood developed in Section 12.4, the layered account of subjecthood developed in Section 4.12, and the plural value architecture developed in Section 14.11 to the capability asymmetries and participatory conditions of artificial intelligence. Its objective is to identify which distinctions should remain visible when human persons, artificial agents, collective formations, and non-human participants enter a shared economic field. The discussion proceeds through these four subject forms, incommensurable value, heterogeneous coexistence, utility representation, and institutional mediation. The method is conceptual and institutional. It does not assign a common ontology, phenomenology, moral status, or utility function to the subject forms under consideration.

The central analytical object is a *subject–value configuration*. Economic consequences arise through relations among subjects, the dimensions in which they possess standing or capacity, the values that become relevant to those relations, and the institutions that recognize, translate, rank, aggregate, protect, or exclude those values. The same configuration can contain several subject forms and several value orders simultaneously. A person may possess welfare interests, legal rights, capabilities, preferences, attachments, responsibilities, and commitments that are only partially aligned. An organization may possess legally recognized claims, strategic objectives, internal governance rules, and historically inherited purposes without possessing human experience. An artificial system may exercise operational agency or mediate decisions without thereby acquiring every form of standing attributed to persons. An ecosystem may be economically consequential through ecological dependence, stewardship obligations, option value, and the interests of human or non-human life without being representable as a conventional maximizing agent.

Definition 18.248 (Subject–value configuration). A *subject–value configuration* is a historically situated arrangement in which one or more analytically relevant subjects occupy specified positions of participation, capacity, exposure, representation, claim, obligation, dependence, or decision, while one or more value structures organize what counts as benefit, harm, priority, significance, obligation, preservation, or desirable change for the inquiry at hand.

Definition 18.248 is deliberately typed. A subject position and a value structure should be identified with enough precision to show whose or what standing is being represented and through which evaluative register. The definition does not require that every value be possessed as a preference by an individual subject. Values can be articulated through rights, capabilities, institutional purposes, ecological constraints, professional obligations, cultural commitments, legal protections, public reasons, or other historically stabilized evaluative forms.

Table 18.15: Analytical architecture for heterogeneous subjects and value structures in AI-mediated economies.

Subject form	Relevant standing dimensions	Characteristic value relations	Mediation problem
Human persons	Experience, capability, rights, responsibility, participation, historical continuity	Welfare, capability, dignity, attachment, autonomy, care, knowledge, cultural and relational value	Preserving plurality within and among persons while preventing capability asymmetry from erasing consequential voice
Artificial agents	Operational agency, delegated authority, representational role, computational capability, infrastructural position	Task objectives, delegated criteria, encoded priorities, learned representations, institutional purposes	Distinguishing effective agency from attributed standing and locating responsibility for mediated action
Collective subjects	Membership, representation, institutional continuity, joint capacity, shared rules, distributed responsibility	Collective purposes, common goods, public value, organizational commitments, inherited obligations	Preventing internal heterogeneity from disappearing behind unitary representation while retaining collective capacity
Non-human participants	Exposure, ecological dependence, causal participation, stewardship relevance, represented interests	Welfare where applicable, ecological integrity, continuity, option value, interdependence, stewardship commitments	Representing affected positions that may lack conventional institutional voice or market expression
Heterogeneous configurations	Several dimensions distributed across interacting subject forms	Partially comparable, translated, contested, or incommensurable value orders	Governing comparison and action without presuming universal scalarization or complete equivalence

Table 18.15 summarizes the distinctions developed in this section. The table is a diagnostic architecture rather than a ranking of subject forms. Its purpose is to prevent operational capability, institutional recognition, experiential welfare, legal personality, moral standing, and representational authority from collapsing into one category when AI systems make some dimensions increasingly similar while leaving others uncertain or different.

18.15.1 Human Subjects

Human persons enter AI-mediated economic configurations through more dimensions than productive contribution alone. They can be workers, owners, users, citizens, learners, patients, creators, caregivers, dependants, researchers, consumers, community members, rights-holders, and persons exposed to decisions made through technical systems. Their standing can therefore be expressed through welfare, capability, legal rights, social membership, lived experience, responsibility, participation, and historically formed attachments. Section 12.4 already estab-

lished that economic subjecthood should be indexed to the dimensions relevant to a specified inquiry. The AI case makes that discipline more consequential because machines can increasingly approximate, exceed, or substitute for selected human performances while leaving many other dimensions of human subjecthood analytically untouched.

A performance comparison therefore supplies only one coordinate of a human subject's economic position. An artificial system may produce a more accurate forecast, write faster, search a larger corpus, or coordinate a larger number of transactions. Such capability differences can alter bargaining position, employment demand, access to institutions, and dependency. They do not by themselves determine the value of a person's welfare, legal claims, social membership, experiential interests, or participation in collective self-organization. The relevant economic question is how capability asymmetry changes the relations through which these dimensions are realized, protected, or weakened.

Human subjects are also internally heterogeneous. Preferences can conflict with commitments; immediate welfare can conflict with long-horizon capability; family obligations can conflict with occupational incentives; individual benefit can conflict with community continuity; stated choice can differ from reflective judgment under changing information. A human subject should therefore not be represented automatically by one revealed or declared utility function when the inquiry concerns several dimensions of value. A compact scalar can be useful for specified decisions, yet its adequacy depends on whether the omitted dimensions are immaterial to the question being asked.

AI mediation can change which dimensions become institutionally visible. Platforms can make clicks, purchases, response times, ratings, productivity measures, or engagement signals highly legible while leaving care, hesitation, uncertainty, cultural attachment, tacit knowledge, or unexpressed vulnerability weakly represented. The resulting data asymmetry can create a representational asymmetry: what is easiest to encode can become easiest to optimize, audit, or reward. Human subjecthood then risks being institutionally reconstructed around the dimensions that technical systems can observe most readily.

This reconstruction is economically consequential because representation can feed back into later opportunity. A person classified as low risk, high value, employable, unreliable, engaged, productive, or eligible can encounter different credit, work, insurance, education, platform, or public-service pathways. Section 4.12 distinguished relationally effective subjecthood from its manifestations and representations. In an AI-mediated economy, the distance among these registers deserves explicit attention because automated representations can become operational at large scale and high speed.

Proposition 18.249 (Human subject multidimensionality). *Where an AI-mediated economic decision materially affects several dimensions of human standing, adequacy requires that the analysis identify the dimensions relevant to the decision and justify any operation that compresses them into a single representation. Operational performance in one dimension does not establish equivalence across the remaining dimensions.*

Proposition 18.249 does not require maximal description of every person. It

requires proportionality between the stakes of the decision and the dimensions retained by the representation. A narrow scheduling problem may legitimately use a narrow objective. A decision concerning livelihood, health, legal status, educational access, or long-term participation can require a richer representation because the downstream consequences span more of the subject's economic life.

The same principle preserves agency without idealizing autonomy. Human decisions are relationally conditioned by information, institutions, dependence, history, culture, embodiment, and available alternatives. AI can expand agency by supplying knowledge, translation, accessibility, simulation, or assistance. It can also narrow agency when recommendation, default, ranking, surveillance, or dependency structures make some alternatives practically inaccessible. Human subjecthood under AI is therefore better represented through the changing architecture of capacities and relations than through an assumption of either complete autonomy or complete technological determination.

18.15.2 Artificial Agents

Artificial systems can occupy economically consequential positions even when questions concerning consciousness, experience, moral status, or ultimate ontology remain unresolved. They can initiate transactions within delegated limits, allocate attention, generate symbolic outputs, coordinate workflows, recommend decisions, negotiate through software interfaces, monitor infrastructures, and act on behalf of persons or organizations. Chapter 18 has therefore used the language of artificial productive capacity and artificial economic agency in an operational sense. Section 18.15 sharpens the standing of that language by distinguishing effective agency from broader subjecthood claims.

Three layers are especially important. First, an artificial system can possess *operational capacity*: it can transform inputs, maintain state, select among actions, or alter an economic environment. Second, it can possess *delegated or institutionally recognized authority*: an organization may permit its outputs to trigger payments, access decisions, contractual steps, resource allocation, or other consequences. Third, observers may attribute stronger forms of subjecthood, including intention, responsibility, welfare, or moral standing. The first two layers can be empirically and institutionally specified without resolving the third.

This layered account helps analyze increasingly autonomous systems without forcing premature ontological conclusions. A system that purchases computing resources, hires digital services, or manages an investment strategy through delegated credentials can have economically consequential agency. The system's action may still be legally attributed to an organization, technically constrained by infrastructure providers, financially bounded by an account owner, and normatively governed by human institutions. The relevant subject-value configuration therefore includes the artificial agent and the relations through which its capacity becomes authorized, recognized, financed, or contestable.

Artificial agents also inherit value structures rather than entering the economy free of them. Objectives can be specified through reward functions, instructions, constitutional constraints, access rules, organizational policies, legal requirements, train-

ing distributions, evaluation procedures, or patterns learned from human-produced data. These mechanisms differ substantially, yet they share one analytical feature: an artificial system's operative criteria are historically produced within a wider relational field. A system can subsequently transform or recombine those criteria in ways that are difficult to anticipate, but its action remains situated within technical and institutional conditions that make some objectives, representations, and actions available.

The phrase *AI values* therefore requires discipline. It can refer to encoded optimization criteria, stable behavioral tendencies, learned representations of human evaluations, inferred user preferences, or hypothetical machine welfare claims. These objects should not be conflated. A model's optimization target is analytically different from a person's experienced good; a learned preference model is different from the preferences it represents; a system's persistent behavioral policy is different from institutional authorization to act. The distinctions matter because each object creates different governance questions.

Responsibility is especially sensitive to this separation. Increasing artificial agency can distribute causal contribution across developers, deployers, users, infrastructure providers, data curators, organizations, regulators, and automated components. A system's operational autonomy can therefore increase while human or institutional responsibility becomes more difficult to localize. GRE should analyze that distribution rather than infer responsibility directly from causal efficacy. Section 16.16 developed institutional governance as a means of organizing responsibility across relational structures; the AI case supplies an especially demanding application.

Proposition 18.250 (Artificial agency–standing separation). *Operational agency, delegated authority, institutional recognition, experiential welfare, legal personality, moral standing, and responsibility are analytically separable dimensions. Evidence that an artificial system satisfies one dimension supports claims about another only where an additional argument or institutional rule establishes the relation.*

Proposition 18.250 permits strong claims where the evidence is strong. An artificial system can clearly be causally effective, computationally capable, or institutionally authorized without the analysis pretending that these observations resolve questions that require phenomenological, legal, ethical, or political argument. This restraint is especially important in a rapidly changing technical environment where operational similarity may arrive earlier than consensus about the meaning of that similarity.

Artificial agents can also become representational intermediaries for other subjects. A personal AI may negotiate purchases, summarize information, express preferences, or interact with institutions. An organizational AI may represent a firm in routine transactions. A public-sector system may mediate eligibility or service access. The artificial agent then becomes part of the representation relation itself. Governance must ask what authority has been delegated, how faithfully the system represents the relevant subject, what happens when the representation diverges, and how affected positions can correct or contest the result.

18.15.3 Collective Subjects

Collective subjects include households, firms, public bodies, communities, associations, research groups, cooperatives, movements, and other configurations whose relations generate capacities that cannot be represented adequately as a simple sum of isolated individual actions. Their relevance to AI-mediated economies is twofold. Collective organizations control much of the infrastructure through which artificial capability is developed and deployed, and collective formations also provide the institutions through which persons can pool resources, articulate common purposes, exercise counter-power, preserve knowledge, and sustain participation.

Collective subjecthood requires a distinction between collective capacity and internal unanimity. A firm can sign a contract, own an asset, operate a model, or coordinate a workforce through institutional procedures even when its members disagree. A community can preserve a language, maintain a commons, or organize mutual support without possessing one homogeneous preference. A public body can exercise statutory authority while containing political disagreement and administrative plurality. Treating these formations as subjects can therefore be analytically useful, provided that the representation does not erase the internal relations through which collective decisions are produced.

AI can strengthen collective capacity by reducing coordination costs, supporting shared knowledge, enabling translation, assisting administration, and expanding access to technical expertise. The same technologies can centralize authority when model access, data, verification, or decision interfaces are controlled by a narrow managerial or technical layer. A collective can therefore become more capable externally while becoming less participatory internally. Capability growth at the collective level and participation at the member level should consequently be tracked separately.

Representation is the key interface. Collective subjects act through offices, delegates, voting rules, managers, committees, legal agents, protocols, databases, and increasingly artificial systems. Each representative mechanism selects which information enters collective action and which interests or values become legible. An AI system used to summarize member preferences, prioritize cases, draft policy, or allocate internal resources can alter the effective constitution of the collective even when formal governance rules remain unchanged. The representational layer becomes part of the collective's generative architecture.

Collective values can likewise have several sources. They may arise through explicit constitutional commitments, negotiated purposes, inherited practices, professional norms, legal mandates, cultural identity, shared infrastructure, or repeated coordination. These values can persist across membership turnover and can constrain current members. Persistence does not establish unanimity or intrinsic moral authority; it establishes a historically effective evaluative structure that can shape action and require analysis.

A useful distinction therefore separates *collective purpose* from *aggregate preference*. Aggregate preference summarizes individual evaluations according to a specified rule. Collective purpose can additionally depend on institutional history, role obligations, constitutional commitments, common goods, or relations that

exist only at the collective scale. A university's research mission, a court's legal function, a cooperative's member-governance commitments, or a community's language-preservation project cannot always be reconstructed adequately by adding contemporaneous individual preferences.

Proposition 18.251 (Collective representation condition). *Where a collective subject is treated as a unit of AI-mediated decision or action, analysis should identify the mechanism through which collective standing is represented and preserve materially relevant internal heterogeneity when that heterogeneity affects authority, incidence, responsibility, or the legitimacy of the resulting action.*

The proposition protects two analytical goods simultaneously. It preserves the reality of collective capacity while keeping visible the internal structure through which that capacity is generated. This matters particularly under radical capability asymmetry because organizations with advanced AI can acquire substantial external power even when the distribution of control within those organizations remains concentrated or opaque.

Collective subjects also provide a bridge between individual and system-level governance. Persons rarely negotiate directly with every infrastructure, model provider, market, state, or platform that conditions their economic lives. Associations, unions, professional bodies, municipalities, cooperatives, research institutions, civil-society organizations, and public agencies can mediate these relations. The strength, accessibility, and pluralism of collective subjects can therefore shape whether individual persons encounter AI asymmetry as isolated dependence or through institutions capable of bargaining, verification, shared learning, and contestation.

18.15.4 Non-Human Subjects

GRE's broad definition of economic subjecthood permits non-human participants to enter an inquiry where they occupy economically consequential positions of exposure, dependence, causal participation, representation, stewardship, or claim. This analytical inclusion does not require all non-human entities to be modeled as agents, legal persons, or welfare subjects. It allows inquiry to follow economic consequences beyond the conventional boundary of human and organizational decision makers when ecological systems, animals, species, landscapes, or other living and material configurations materially condition or bear the consequences of economic action.

AI expands the relevance of this issue because artificial systems can alter the scale, speed, and informational resolution at which non-human conditions become actionable. Remote sensing, ecological modeling, automated monitoring, optimization, robotics, and predictive systems can make some ecological relations newly legible and can support stewardship or restoration. They can also intensify extraction, surveillance of natural systems, resource targeting, or optimization around indicators that omit ecological relations not represented in the model. Greater information therefore does not by itself determine how non-human value enters economic decision.

Several forms of standing should remain distinct. Sentient animals can raise welfare questions. Species and ecosystems can be relevant through ecological continuity, interdependence, resilience, option value, stewardship obligations, or legally recog-

nized protections. Rivers, forests, or landscapes can acquire institutional standing through particular legal or cultural arrangements. Infrastructure and material systems can be economically indispensable without possessing welfare or moral standing. The category *non-human subject* is therefore an analytical umbrella whose specific standing must be stated in each application.

Representation poses an asymmetry because many non-human affected positions cannot enter conventional deliberation through direct linguistic participation. Human institutions represent them through science, stewardship, guardianship, law, customary practice, ecological indicators, ethical argument, or political advocacy. AI can assist these forms of representation by processing complex ecological information, yet the model's output remains mediated through choices about variables, timescales, baselines, thresholds, and optimization criteria. The representational problem is consequently institutional as well as technical.

Temporal scale is particularly important. Human economic decisions can be evaluated over electoral cycles, budget years, market horizons, or individual lifetimes, while ecological consequences can unfold across much longer or differently structured periods. A value architecture that discounts or omits these horizons can systematically weaken non-human standing even without explicit exclusion. AI-driven optimization can amplify that effect if the objective function inherits the same horizon.

The non-human case also clarifies why affectedness and agency should not be collapsed. A configuration can be profoundly affected by an economic process without having the capacity to bargain, choose, or represent itself. Conversely, a computational agent can possess extensive operational agency without evidence of experienced welfare. These are different axes of subjecthood. Governance under heterogeneous subjects must therefore specify which axis grounds a claim, protection, responsibility, or decision right.

Proposition 18.252 (Affectedness–agency separation). *Economically relevant affectedness and effective agency are independent analytical dimensions. Institutions can therefore have reason to represent or protect a position that lacks conventional agency, while high operational agency does not by itself establish welfare-bearing or moral standing.*

Proposition 18.252 becomes especially useful in mixed human–AI–ecological systems. It permits the same economic analysis to represent a human community's participatory claims, an artificial system's operational role, an organization's decision authority, and an ecosystem's exposure without forcing those positions into one undifferentiated category of actor.

18.15.5 Incommensurable Values

Heterogeneous subjects become a deeper economic problem when their relevant values cannot be translated into one common measure without remainder. Chapter 14 treated value as plural, historically generated, relationally realized, transmitted, converted, accumulated, contested, and sometimes only partially commensurable. Section 14.11 further distinguished comparison, commensuration, translation, monetization, aggregation, and plural decision architecture. The present subsection applies

that discipline to AI-mediated configurations in which different subject forms and different standing dimensions coexist.

Incommensurability can arise in several ways. Two values can lack a common cardinal unit. They can be comparable only under particular institutional purposes. One value can be expressible only through a threshold or prohibition. Translation can preserve part of the source while losing context or meaning. Two subject positions can disagree about what constitutes a gain. A value can change through the act of measurement or representation. These cases should not be collapsed into a single claim that comparison is impossible. They indicate different limits on the kind of comparison that is warranted.

AI can intensify pressures toward commensuration because computational systems often require explicit objectives, labels, scores, rankings, probabilities, or action-selection criteria. These representations can be indispensable for operation. Their existence nevertheless does not establish that the represented values were fully commensurable before encoding or that the chosen scalar preserves every relevant distinction. The technical need for a decision variable is therefore different from an argument that the variable exhausts the value field.

Consider a system allocating educational support. It may balance predicted attainment, learner preference, equity, psychological burden, teacher capacity, institutional mission, and long-horizon capability. A model can combine these into a score, optimize one while treating others as constraints, maintain a vector of outcomes, or leave some decisions to deliberation. Each architecture embodies a different relation among values. The decision to scalarize is itself an institutional choice and can redistribute power toward the actors who specify the weights, data, and admissible objectives.

The same issue appears in environmental management, health, labor allocation, research funding, public administration, platform governance, and cultural institutions. AI can make sophisticated multi-objective optimization technically feasible while leaving normative questions about admissible trade-offs unresolved. More computational capacity therefore increases the range of representable decision procedures without eliminating the need to justify the evaluative architecture.

GRE can preserve this distinction through the concept of an *evaluative remainder*. Chapter 14 used remainder to describe significance lost or left unresolved through conversion, aggregation, or translation. Under AI, such remainder should be recorded where it materially affects affected positions or later revision. A system that chooses among options can close an action problem while leaving part of the value problem open.

Definition 18.253 (Subject–value remainder). A *subject–value remainder* is materially relevant evaluative information, standing, disagreement, uncertainty, or significance associated with a subject position that is not preserved by the representation, translation, weighting, aggregation, or optimization procedure used to support an AI-mediated decision.

Definition 18.253 makes omission traceable without implying that every remainder invalidates a decision. Institutions routinely act under incomplete representation. The analytical requirement is to distinguish tolerable abstraction from omission that

changes incidence, standing, reversibility, or the capacity for later contestation.

Proposition 18.254 (Decision closure and evaluative remainder). *An AI-mediated decision can reach operational closure while its evaluative ordering remains incomplete. Where unresolved subject–value remainder can materially affect later review, compensation, restoration, participation, or institutional legitimacy, preserving that remainder strengthens the revisability of the decision architecture.*

The proposition is particularly important under high-speed or large-scale automation. A system may need to decide repeatedly and quickly, yet institutional records can preserve uncertainty, dissent, omitted criteria, or exceptional cases for later inspection. AI therefore need not force evaluative closure merely because operational closure is required.

18.15.6 Heterogeneous Subject–Value Coexistence

A shared economic field can contain subjects whose capacities, forms of standing, temporal horizons, and value structures differ substantially. Coexistence refers here to the institutional condition under which these heterogeneous positions can remain consequential within one economic order without requiring complete assimilation into one subject model or one value metric. The relevant problem is neither simple tolerance nor permanent separation. It is the organization of relations through which heterogeneous subjects can interact, coordinate, contest, exchange, cooperate, withdraw, or remain protected where translation is incomplete.

Several coexistence forms are possible. Some relations can be governed through common rules that apply despite different motivations. Others can rely on negotiated interfaces between institutions with different purposes. Some values can be translated partially for a bounded decision while retaining their source-specific meaning elsewhere. Some claims can be protected through thresholds or rights rather than traded against every competing objective. Some domains can remain intentionally plural, allowing several organizational forms or technological pathways to coexist.

AI can support coexistence by reducing translation costs, making complex constraints legible, enabling personalized interfaces, simulating consequences for different groups, and maintaining several evaluative dimensions simultaneously. It can also weaken coexistence when a dominant model, platform, ontology, language, or scoring system becomes the obligatory interface through which heterogeneous subjects must become legible. The issue is therefore not whether AI standardizes; some standardization is necessary for coordination. The issue is which distinctions the standard preserves, which it suppresses, and whether alternative interfaces remain practically available.

This problem is especially acute where artificial agents mediate interaction among humans or institutions that possess different normative orders. A system trained to negotiate contracts, moderate communication, allocate shared resources, or translate policy preferences can become a de facto mediator among value systems. Its representation architecture then influences which differences are treated as negotiable, which are interpreted as errors, and which remain visible as legitimate disagreement. Mediation quality therefore depends partly on the capacity to preserve typed differences rather than forcing every input into one homogeneous preference space.

Coexistence also requires attention to exit and re-entry. A subject can be formally free to reject an AI-mediated institution while lacking a practical alternative because work, payments, public services, education, or communication depend on the same infrastructure. Genuine plurality therefore depends on the generative action space developed in Section 18.13: alternative institutional pathways need sufficient capability, interoperability, resources, and legitimacy to remain usable.

Definition 18.255 (Heterogeneous coexistence). *Heterogeneous coexistence* is an institutional condition in which materially distinct subject forms or value structures can participate in a shared economic field through recognized relations, interfaces, protections, or procedures while retaining differences whose elimination is not required for the coordination problem at hand.

The definition does not imply harmony. Coexistence can include disagreement, bargaining, conflict, asymmetric dependence, and revision. Its stronger form requires procedures for contestation and change because a fixed coexistence arrangement can stabilize unjust relations. Section 16.19 developed governance under heterogeneous values precisely as an institutional problem rather than a demand for prior consensus.

A further distinction concerns coexistence across scales. A local community may preserve a value practice within a national regulatory framework; an organization may maintain an internal mission while participating in markets; a person may use an AI assistant governed by platform rules while retaining personal evaluative commitments outside the platform. Compatibility can therefore be partial and nested. The requirement is not one universal reconciliation but enough interface structure for interaction without erasing the distinctions that remain material.

Proposition 18.256 (Coexistence without equivalence). *Coordination among heterogeneous subjects does not require proof that their subject forms or value structures are equivalent. A sufficient institutional interface can support bounded cooperation, exchange, representation, protection, or joint decision while preserving unresolved differences outside the scope of that interface.*

Proposition 18.256 is central to the chapter's treatment of AI. Artificial systems can become powerful interfaces precisely because they can translate among languages, representations, and task structures. The existence of such translation should not be treated as evidence that the translated systems have become identical. Preserving the remainder of translation protects both analytical accuracy and the possibility of future revision.

18.15.7 Utility Representation and Value Heterogeneity

Utility representations remain valuable tools for many economic problems. They can formalize preference, support decision under uncertainty, enable optimization, and make trade-offs explicit under specified assumptions. The difficulty arises when one representation is extended beyond the domain in which its comparability assumptions are warranted. AI-mediated economies increase both the practical power of utility-like representations and the cost of treating their scope as self-evident.

A utility function can represent one subject's ordered preferences over a defined

option set, an organization's operational objective, a social welfare criterion, a learned reward model, or a platform's engagement target. These are different analytical objects even when all are represented numerically. Their numerical similarity does not establish that the underlying values share the same source, standing, or interpretation. A person's preference ordering, a corporation's profit objective, and a model's reward signal can therefore enter one computational procedure while remaining heterogeneous in meaning.

Three levels of scalarization should be distinguished. *Within-subject scalarization* compresses several considerations relevant to one represented subject. *Cross-subject scalarization* constructs a comparative or aggregate measure across subjects. *Cross-form scalarization* combines qualitatively different value forms such as income, health, ecological loss, cultural continuity, participation, or rights. Each level can be useful, but each introduces stronger assumptions about representation and commensurability.

AI systems can conceal these assumptions because optimization occurs after scalarization has already been embedded in data pipelines, evaluation criteria, reward models, procurement specifications, or institutional targets. The visible technical question may concern model accuracy while the more consequential normative choice occurred earlier when the objective was constructed. GRE therefore treats objective construction as part of economic architecture rather than as a neutral preprocessing step.

Vector-valued, constrained, lexicographic, threshold-based, partially ordered, deliberative, or rule-governed architectures can preserve more heterogeneity where a single scalar would remove material structure. These alternatives do not automatically produce better decisions. They trade simplicity for retained information and can introduce their own governance difficulties. Their relevance lies in showing that algorithmic decision does not logically require one universal utility representation.

The strongest caution concerns the movement from operational necessity to ontological or normative conclusion. A system may require a scalar score to rank search candidates under a latency constraint. That fact establishes a property of the operational architecture. It does not establish that the persons, organizations, ecosystems, or values affected by the ranking possess one universal scalar value. The same distinction applies to reinforcement learning, recommender systems, risk scoring, and resource allocation.

Proposition 18.257 (Scalarization scope condition). *A scalar utility or objective representation is adequate for an AI-mediated economic task to the extent that the dimensions compressed by the representation are either immaterial to the task or are incorporated through justified comparison, weighting, constraints, thresholds, or institutional safeguards. Adequacy for one task does not establish adequacy for the wider subject-value configuration in which the task is embedded.*

The proposition preserves ordinary economic modeling while making scope explicit. A production optimizer can remain a production optimizer. Difficulty arises when its objective silently becomes the criterion for labor policy, environmental impact, community continuity, or public legitimacy without an additional evaluative argument.

A plural architecture can also combine scalar and non-scalar elements. Institutions may optimize cost subject to rights constraints, maximize service coverage subject to minimum quality standards, use a multi-criteria dashboard followed by deliberation, or authorize automated decisions only inside a domain defined by law and appeal rights. Such hybrid structures often describe real economic governance more accurately than the image of one unconstrained maximand.

18.15.8 Institutional Mediation

Heterogeneous subject–value configurations become governable through institutions that determine standing, representation, admissible evidence, decision rules, rights, obligations, translation procedures, appeals, review, and revision. Institutional mediation is therefore the mechanism through which subject heterogeneity becomes economically actionable without requiring prior agreement on one ontology or one value metric. Its role is especially important under AI because artificial systems can operate across institutional interfaces at speeds and scales that exceed the capacity of affected subjects to inspect each individual decision.

Institutional mediation begins with standing rules. Institutions decide whose interests or claims can enter a process and in what form. A person may possess direct standing; a child, future generation, animal, ecosystem, organization, or diffuse public may be represented through guardians, trustees, public agencies, scientific bodies, legal procedures, or other arrangements. An artificial agent may possess delegated transactional authority while responsibility remains institutionally attached elsewhere. These rules construct the practical subject field within which AI operates.

Representation rules then determine how a subject's relevant values become legible. Surveys, preferences, rights, capability indicators, legal claims, expert assessments, ecological measurements, organizational missions, community deliberation, and model-generated proxies each preserve different structures. Strong mediation therefore requires provenance: decision makers should be able to identify which subject position a representation concerns, which value dimension it expresses, how it was generated, and what transformations occurred before it entered the decision process.

Translation rules determine when values can be compared or converted. A procurement system may monetize cost while treating safety as a threshold. A public institution may use legal rights as side constraints while balancing service quality and fiscal burden. A research organization may combine peer assessment, strategic priorities, feasibility, and portfolio diversity. AI can assist each procedure, but the legitimacy of the translation comes from the institutional rule and its justification rather than from computational sophistication alone.

Contestability supplies a further layer. Heterogeneous subjects can be misrepresented, excluded, or compressed by technical systems. An institution therefore needs pathways through which affected positions can challenge factual errors, question the relevance of criteria, contest weights, introduce omitted values, or seek human or collective review. Section 18.13 treated contestability and reversibility as elements of governance under radical asymmetry. The present section adds that contestability should be sensitive to the type of subject and value at issue. Correcting a data error

differs from disputing an institutional objective or asserting a previously unrepresented form of standing.

Institutional mediation also allocates responsibility for unresolved remainder. A technical system cannot by itself determine which omitted values deserve preservation, compensation, or priority unless those decisions have already been encoded through institutional authority. Where value conflict remains open, governance may assign the decision to courts, public agencies, professional bodies, democratic procedures, community institutions, negotiated agreements, or mixed processes. AI can supply analysis, simulation, translation, or administrative support while the institution retains responsibility for the rule under which closure occurs.

Definition 18.258 (Subject–value mediation interface). *A subject–value mediation interface is an institutional, legal, organizational, technical, epistemic, or deliberative arrangement that specifies how identified subject positions and value structures become represented, compared, translated, protected, aggregated, contested, or carried forward into an economically consequential decision or process.*

The definition extends the conversion-interface concept developed in Chapter 14. A subject–value mediation interface can include value conversion, but its scope is wider because it also determines standing, representation, and procedural authority. A court, standards body, market, platform, public consultation process, professional review board, community assembly, regulatory procedure, or AI-assisted administrative system can each function as such an interface under different conditions.

Several qualities strengthen these interfaces. *Typed standing* keeps distinct the dimensions through which a subject enters the process. *Provenance* records how representations were generated. *Remainder preservation* retains materially relevant information lost through simplification. *Contestability* permits correction and disagreement. *Revisability* allows rules to change as technologies, evidence, and subject configurations evolve. *Distributed mediation* can reduce dependence on a single institutional or technical gatekeeper where plurality is valuable. These qualities need not be maximized in every process; their appropriate degree depends on stakes, scale, reversibility, and available resources.

Proposition 18.259 (Mediation adequacy under heterogeneous subjects). *An institutional arrangement has stronger adequacy for a heterogeneous AI-mediated economic configuration when it identifies materially relevant subject positions, distinguishes the dimensions of standing attached to them, makes its value-translation and decision rules inspectable, preserves significant subject–value remainder, and provides revision or contestation pathways proportionate to the stakes and reversibility of the decision.*

Proposition 18.259 does not define one ideal institution. It specifies a diagnostic direction for comparing architectures that perform different economic functions. A low-stakes automated transaction can rely on a compact interface. A system affecting legal status, health, livelihood, political participation, ecological continuity, or durable access to essential infrastructure may require a richer one.

Institutional mediation also connects heterogeneity to power. The actor that controls the interface can influence which subjects become visible, which values can be expressed, which translations are admissible, and which forms of contestation remain available. Control over mediation can therefore convert technical or orga-

nizational capability into structural power even when the controller does not determine every downstream decision. Section 16.1 established that asymmetry becomes power through relational conversion mechanisms; subject–value mediation supplies one such mechanism in AI-rich economies.

The section’s argument can now be stated compactly. Human persons, artificial agents, collective formations, and non-human participants can occupy the same economic field without possessing identical forms of subjecthood. Their relevant values can be partially comparable, translatable, or aggregable while retaining meaningful differences and remainder. AI increases the feasibility of coordinating complex heterogeneous systems, yet it also increases the practical force of whichever representations and objectives are encoded in technical and institutional interfaces. Governance therefore requires explicit subject typing, value provenance, bounded translation, remainder preservation, contestability, and revisability where the stakes justify them.

This architecture changes the temporal problem that follows. Once subject positions, value structures, and mediation interfaces are allowed to evolve, the composition of the economic order itself becomes path dependent. Dependencies can deepen or weaken; human and artificial capabilities can co-evolve; institutions can acquire or lose mediating capacity; forms of work and participation can reorganize; knowledge infrastructures can become more plural or more concentrated. Section 18.16 therefore examines long-horizon human–AI order as a trajectory problem rather than a static equilibrium among fixed subject types and fixed values.

18.16 Long-Horizon Human–AI Order

This section develops the temporal synthesis of Chapter 18. Its role is to connect the chapter’s analyses of artificial productive capacity, capability asymmetry, power, labor, subjecthood, ownership, surplus, epistemic dependence, governance, generative participation, and heterogeneous subject–value mediation within one historically extended account of human–AI economic order. The objective is to identify which trajectories require simultaneous attention when present arrangements can alter the capacities, dependencies, institutions, forms of participation, and knowledge conditions inherited by later periods. The discussion proceeds through dependency, capability, institutional, labor, participation, and knowledge trajectories before examining future-possibility openness and the discipline of revisable closure. The method combines the trajectory and path-dependence architecture of Chapter 15, the adaptive-governance architecture of Section 16.20, and the AI-specific mechanisms developed in Sections 18.1–18.15. The section is therefore prospective without functioning as a forecast: it analyzes possible trajectory structures and governance conditions rather than asserting one determinate future of artificial intelligence.

A long-horizon analysis becomes necessary because many economically important effects of AI can be weakly visible in a short observational window. A system can improve current service quality while deepening infrastructural dependence. Automation can increase output while altering the institutions through which later workers acquire expertise. A public body can reduce administrative cost while gradually los-

ing the internal capacity required to supervise the systems on which it depends. A community can gain access to powerful models while losing locally governed knowledge infrastructures. Present performance and future generativity can therefore move in different directions.

Chapter 15 defined trajectories as scale- and representation-indexed accounts of historically extended change and emphasized that economic histories are often bundles of partially coupled trajectories rather than movements along one variable. That discipline is especially important for human-AI order. Dependence, capability, institutional authority, labor organization, participation, and knowledge can change at different rates, react to different interventions, and produce delayed effects in one another. A short-run improvement in one trajectory can reinforce a long-run deterioration in another, while a costly short-run transition can sometimes preserve or create later capacities.

Definition 18.260 (Long-horizon human-AI order). *A long-horizon human-AI order is a historically extended configuration of relations among human persons, artificial systems, collective subjects, non-human affected positions, institutions, infrastructures, and value structures, represented through the coupled trajectories by which dependency, capability, labor, participation, knowledge, authority, and future-option formation change over time.*

Definition 18.260 treats order as a changing relational configuration rather than a fixed equilibrium. The term does not imply harmony, stability, or a single center of control. An order can be contested, fragmented, rapidly changing, or only partially institutionalized. What makes it analytically an order is that recurrent relations, infrastructures, standards, rights, dependencies, and expectations acquire enough persistence to condition later action.

Table 18.16 summarizes the trajectory dimensions used in the section. The rows are analytically distinct but empirically coupled. Their separation helps identify which mechanism is changing; their recombination is required for interpretation of the wider order.

Proposition 18.261 (Coupled-trajectory condition). *A long-horizon assessment of human-AI order is stronger when it evaluates materially coupled dependency, capability, institutional, labor, participation, and knowledge trajectories rather than inferring the wider order from improvement or deterioration in one dimension alone.*

Proposition 18.261 supplies the section's governing discipline. Productivity, income, model capability, access, employment, participation, and epistemic autonomy remain important indicators, yet none provides a sufficient summary of the order by itself. The analytical task is to identify which trajectory is being measured, which other trajectories it conditions, and whether the relevant coupling is contemporaneous, delayed, cumulative, threshold-dependent, or reversible.

18.16.1 Dependency Trajectories

Dependency under AI is temporally structured. Section 18.3 distinguished capability asymmetry from the mechanisms through which dependency, control, and institutional mediation can convert asymmetry into power. Section 18.13 then treated de-

Table 18.16: Trajectory dimensions in long-horizon human–AI order

Trajectory	Primary object of change	Typical coupling	Long-horizon concern
Dependency	Reliance, substitutability, exit, fallback, and complementary infrastructure	Infrastructure, access, standards, organizational competence	Whether present reliance becomes difficult to revise or replace
Capability	Human, artificial, organizational, and collective capacities for action and generation	Learning, automation, delegation, investment, maintenance	Whether capabilities regenerate, differentiate, or atrophy across periods
Institutional	Rules, authority, representation, administrative capacity, and governance interfaces	Procurement, law, standards, expertise, public capacity	Whether institutions retain capacity to supervise and revise AI-mediated arrangements
Labor	Tasks, occupations, bargaining structures, income channels, professions, and learning pathways	Automation, ownership, distribution, education, participation	Whether work transitions preserve material security, capability formation, and alternative contribution pathways
Participation	Consequential entry into knowledge, decisions, institutions, care, community, and culture	Rights, time, infrastructure, collective organization, recognition	Whether participation remains generative rather than merely formal
Knowledge	Production, verification, preservation, transmission, orientation, and epistemic infrastructure	Models, archives, education, provenance, research institutions	Whether knowledge capacity remains reconstructible, contestable, and generative

pendency reduction as one governance strategy. A long-horizon view adds a further question: how does reliance change after repeated use, complementary investment, institutional adaptation, skill redistribution, and withdrawal of alternatives?

A dependency trajectory can deepen even when each individual period appears beneficial. An organization can adopt an external model because it is cheaper and more capable than the available internal alternative. Staff then reorganize work around the model, data formats become platform-specific, procurement routines stabilize, internal expertise declines, and complementary software is built around the same provider. None of these changes alone establishes problematic dependence. Together they can alter the cost and feasibility of later exit. The relevant object is therefore the history through which reliance becomes embedded.

Several dimensions should be distinguished. *Functional dependency* concerns reliance on an artificial system for a task or service. *Infrastructural dependency* con-

cerns reliance on compute, networks, data pipelines, energy systems, model-serving architecture, or technical standards. *Organizational dependency* concerns loss of internal personnel, routines, or authority required to perform or supervise a function. *epistemic dependency* concerns reliance on a system for interpretation, verification, or orientation. *institutional dependency* concerns rules or public processes that cannot operate effectively without particular technical intermediaries. These dimensions can reinforce one another while remaining analytically distinct.

Dependency also has a temporal direction because replacement capacity requires time. An institution that retains source data, documentation, interoperable formats, technical staff, and alternative procurement pathways can often change providers more readily than an institution that has allowed those capacities to disappear. A nominal right to exit therefore differs from an effective capacity to exit. The difference can become substantial when restoration requires rebuilding teams, archives, training systems, legal authority, or infrastructure that were gradually displaced.

This temporal structure can produce hysteresis. A dependency may remain after the original efficiency advantage narrows because complementary investments, habits, standards, learned expectations, and institutional routines continue to favor the incumbent arrangement. Section 15.8 treated hysteresis and lock-in as distinct path-dependent conditions. The present application suggests that human-AI dependency should be diagnosed through the mechanisms that preserve reliance after its initiating conditions change rather than through provider concentration alone.

Dependency trajectories can also weaken constructively. Interoperability, modular architecture, portability, open standards, retained human competence, plural procurement, public or commons infrastructure, and credible fallback arrangements can reduce the cost of switching or redesign. Such measures need not eliminate reliance on AI. They can change its form from dependence on one narrow pathway toward dependence embedded in a wider ecology of substitutable or collectively governed resources.

A further issue concerns asymmetric restoration time. The removal of a capability can occur faster than its reconstruction. A training program can be closed in one budget cycle while professional competence takes years to rebuild. A public technical unit can be dissolved quickly while institutional knowledge, recruitment networks, and trust require much longer to restore. Long-horizon governance should therefore attend to the time required to regenerate alternatives, not only the current number of alternatives.

Proposition 18.262 (Dependency-revisability condition). *A dependency trajectory is more compatible with long-horizon revisability when affected subjects retain practical substitutability, interoperable records and interfaces, relevant internal or collective competence, and credible pathways for replacement or redesign within a time horizon proportionate to the consequences of failure or disagreement.*

The proposition does not treat independence as a universal objective. Complex economies depend on infrastructures, institutions, expertise, and other persons. The relevant issue is whether dependence becomes a mechanism of durable power that removes practical alternatives or weakens future capacity to reconstruct them. A well-governed human-AI order can therefore contain extensive interdependence

while retaining sufficient plurality and regenerative capacity to revise how that interdependence is organized.

18.16.2 Capability Trajectories

Capability asymmetry is also historical. Section 18.2 treated human and machine capability as multidimensional, task-relative, and only partially orderable. A long-horizon analysis asks how these capability profiles change through learning, automation, delegation, investment, institutional reorganization, and mutual adaptation. The relevant trajectory is therefore neither a race between two fixed kinds of intelligence nor a single curve of model performance. It is the co-evolution of heterogeneous capacities embedded in different subjects and infrastructures.

Artificial capability can grow through improved models, compute, data, tools, interfaces, coordination systems, and accumulated deployment experience. Human capability can grow through education, practice, collaboration, institutional memory, new conceptual tools, and AI-assisted learning. Collective capability can grow through organizations, standards, public infrastructure, knowledge commons, and forms of coordination that allow individually limited persons to act effectively together. These trajectories can reinforce one another. Better artificial systems can expand human learning and organizational reach, while stronger human and institutional capabilities can improve model evaluation, problem selection, oversight, and socially useful deployment.

The same coupling can produce capability erosion. Repeated delegation can reduce practice in tasks whose competence previously depended on active exercise. Educational pathways can narrow if a capability appears economically unnecessary. Organizations can stop maintaining expertise that an external system supplies more cheaply. Professional communities can weaken when entry routes disappear. The result can be a divergence between *access to capability* and *possession of regenerative capability*: people may be able to obtain an output while losing the capacity to reconstruct, evaluate, modify, or replace the process that produces it.

This distinction matters because capability can be relationally distributed. A person using an AI system may accomplish tasks that neither the person nor the system could perform as effectively in isolation. A municipality can possess a capability through contracts, public staff, legal authority, shared infrastructure, and external expertise. A research community can possess a capability through distributed records, instruments, institutions, and methods. Long-horizon analysis should therefore ask which relations sustain the capability and whether those relations are durable, contestable, and transferable.

Capability inheritance is another temporal concern. Many human capacities are generated through long sequences of education, apprenticeship, mentorship, practice, failure, professional socialization, and participation in communities of inquiry. If AI changes the economic demand for intermediate tasks, it can also change the pathways through which advanced human capability was historically formed. Removing a task from paid work can be efficient at the task level while weakening an apprenticeship structure that served a wider capability-generating function. The appropriate response may involve redesigning the learning pathway rather than preserving

the task unchanged.

Long-horizon capability policy therefore concerns regeneration as well as possession. A society can have high aggregate access to AI while becoming less able to train independent evaluators, public technologists, domain experts, researchers, maintainers, or institutional designers. Conversely, a society can use powerful automation to lower the cost of learning, widen access to advanced tools, and create new forms of collective capability. The direction depends on educational, organizational, ownership, and participation structures rather than on model capability alone.

Proposition 18.263 (Capability-regeneration condition). *A human-AI capability trajectory is more generatively robust when the relations that expand current task performance also preserve or create pathways through which relevant human, collective, and institutional capabilities can be learned, renewed, recombined, and transferred to future participants.*

Proposition 18.263 does not require preservation of every legacy skill. Historical economic change routinely makes some capabilities less useful while creating others. The criterion concerns the capacity to generate and renew capabilities that remain relevant to judgment, verification, governance, care, creation, maintenance, collective action, and future adaptation. A long-horizon order can therefore permit substantial capability substitution while resisting erosion of the capability-generating processes on which later autonomy and innovation depend.

18.16.3 Institutional Trajectories

Institutions mediate the conversion of AI capability into durable economic order. They define rights, authority, procurement, liability, access, representation, standards, review, public obligations, organizational roles, and the interfaces through which heterogeneous subject-value configurations become actionable. Section 18.15 treated these interfaces synchronically. The present subsection examines how their capacities and rules change through repeated AI adoption.

Institutional trajectories contain at least two coupled layers. The *rule layer* includes formal law, regulations, contracts, standards, procedural rights, mandates, and governance rules. The *operative layer* includes staff competence, budgets, routines, technical systems, records, informal practices, organizational memory, and relationships with external providers or affected communities. A rule can remain formally stable while its practical implementation changes dramatically because the operative layer has become AI-mediated. Conversely, institutions can preserve a stable public function while changing the technical means through which it is delivered.

Delegation can alter institutional capacity over time. An agency may initially use an AI system for bounded support while retaining independent review. If performance is high and workloads increase, the system's recommendations can become defaults, staffing can be reorganized, and internal review can shift toward exception handling. The resulting institution may possess greater throughput while having less independent capacity to reconstruct routine decisions. This change can be acceptable under some conditions, yet its significance cannot be assessed from accuracy or cost alone. It alters where practical authority and knowledge reside.

Procurement is similarly generative. Repeated contracts can shape data standards, technical architectures, employment profiles, vendor ecosystems, and future procurement options. A purchasing decision can therefore function as an institutional investment in a pathway. Public and large private buyers can create de facto standards through adoption even before formal standard-setting occurs. Long-horizon analysis should identify these path-creating effects, especially where interoperability and exit become costly only after complementary systems have accumulated.

Institutional memory is another important trajectory. AI can improve records, retrieval, consistency, and continuity when systems preserve provenance and make earlier reasoning reconstructible. It can also weaken memory when model-mediated processes replace records with opaque outputs, when vendor transitions break provenance, or when staff no longer understand why procedures acquired their present form. Section 17.13 developed preservation and re-epistemization as epistemic tasks. For institutions, this implies that the capacity to revisit earlier decisions depends on preserving both outputs and the histories of rules, evidence, interpretations, and technical mediation that produced them.

Institutions can also learn. Monitoring, appeal, audit, incident review, participatory feedback, experimentation, and comparative evaluation can alter rules and deployment architectures. Section 16.20 treated adaptive governance as an iterative process in which rules and governed systems can co-evolve. Human–AI institutions require this capacity because the technical object, the uses made of it, and the affected social relations can change faster than a one-time authorization process can anticipate.

Proposition 18.264 (Institutional self-revision condition). *An institutional trajectory is more compatible with long-horizon governance when the institution retains sufficient authority, competence, records, technical access, fiscal capacity, and contestation pathways to evaluate and revise the AI-mediated arrangements through which its own functions are performed.*

The proposition identifies institutional self-revision as a capability rather than a procedural ornament. An institution that formally retains authority while lacking the expertise, data, contractual rights, or infrastructure required to exercise that authority can become dependent on the object it is supposed to govern. Long-horizon institutional design should therefore examine whether governance capacity co-evolves with deployment capacity rather than assuming that legal jurisdiction alone preserves effective control.

18.16.4 Labor Trajectories

Labor change under AI unfolds through trajectories of tasks, occupations, organizations, bargaining relations, income channels, professional institutions, and capability formation. Section 18.4 separated cognitive automation from broader claims about employment and human contribution. A long-horizon approach extends that distinction by examining how successive rounds of adoption reorganize the pathways through which people enter economic life, acquire skills, receive income, exercise bargaining power, and participate in collective production.

Task displacement and occupational displacement need not coincide. An occupa-

tion can survive while its task composition changes substantially; a profession can expand because AI lowers the cost of complementary work; a role can persist formally while its discretion or learning content declines. Conversely, a new occupational category can emerge around functions that were previously distributed across several roles. Labor trajectories should therefore track task composition, organizational position, bargaining structure, training pathway, and income relation together where those dimensions affect the economic significance of work.

Temporal mismatch is a central problem. Technical capability can change faster than educational systems, professional licensing, bargaining institutions, geographic mobility, housing, care arrangements, or social insurance. A transition that appears efficient in an equilibrium comparison can impose concentrated losses during the period in which persons and institutions cannot adjust at the same rate. Long-horizon analysis should preserve this transition interval rather than treating displaced labor as instantaneously reallocated.

The distributional architecture can also change as wage-based claims become less connected to productive necessity. Sections 18.7 and 18.8 examined AI-generated surplus and the limits of redistribution. Over time, the importance of ownership, access rights, public services, social investment, and non-wage distribution can increase if labor income becomes a weaker channel through which productivity gains circulate. This does not establish one inevitable post-wage regime. It identifies a trajectory problem: institutions built around employment can become increasingly misaligned with the mechanisms through which income and productive capacity are generated.

Labor also carries non-income functions. Work can organize time, social recognition, apprenticeship, collective identity, professional ethics, bargaining power, and participation in institutions. These functions vary across occupations and persons; they should not be romanticized or assumed to justify preserving harmful or unnecessary work. Their analytical relevance lies in transition design. If an occupational form contracts, some of its capability-forming or participatory functions may need alternative institutional locations if society values their continuation.

Care and relational labor illustrate the limits of a single automation metric. AI can reduce administrative burden, improve scheduling, support diagnosis, translate communication, or assist routine monitoring while the value of human presence, trust, embodied care, local knowledge, or mutual recognition remains context-dependent. The labor trajectory can therefore involve re-composition rather than simple replacement. What matters is which tasks move, which relations remain, how quality is assessed, and whether workers and recipients can influence the redesign.

Entry pathways deserve special attention. Many professions reproduce capability through junior work whose immediate output can be relatively easy to automate. If those roles disappear without replacement training structures, the system can enjoy short-run productivity gains while weakening the future supply of experienced practitioners. The same problem can appear in research, law, engineering, administration, medicine, craft, and creative practice in different forms. Long-horizon labor governance should therefore distinguish elimination of low-value routine from elimination of developmental stages that carried hidden learning functions.

Proposition 18.265 (Labor-transition plurality condition). *Assessment of an AI-*

mediated labor trajectory is stronger when it jointly considers income security, task re-composition, bargaining position, capability formation, entry and progression pathways, relational functions, and access to forms of participation outside employment rather than treating employment quantity as the sole transition criterion.

The proposition preserves employment as an important economic variable while locating it within a larger generative architecture. A humane long-horizon order may contain less labor in some domains and more in others; the deeper question is whether transitions preserve material security and the capacities through which persons can continue to learn, contribute, associate, care, create, contest, and participate in future economic formation.

18.16.5 Participation Trajectories

Section 18.14 defined generative participation as consequential involvement in processes that help produce future knowledge, decisions, institutions, care relations, communities, cultural forms, capabilities, or possibilities. A long-horizon perspective asks whether those forms of involvement remain consequential after AI becomes embedded in the institutions through which participation occurs. The distinction between formal participation and effective participation becomes particularly important over time.

A participatory right can remain legally intact while the location of consequential choice changes. Citizens can retain access to consultation while problem framing and option generation migrate into technical systems that are difficult to inspect. Workers can retain representation while staffing, performance evaluation, and task allocation become increasingly model-mediated. Researchers can retain authorship while research agendas become dependent on model-generated problem spaces and platform-controlled infrastructure. Communities can retain cultural institutions while discoverability, funding, and symbolic visibility become concentrated through external platforms. These changes can reduce practical influence without an explicit removal of participatory status.

Participation can also deepen. AI can lower barriers to expertise, translation, drafting, simulation, accessibility, and coordination. Persons previously excluded by language, disability, educational background, geographic isolation, or scarce professional support can gain new ways to enter knowledge and institutional processes. Collective subjects can use AI to analyze documents, organize evidence, compare proposals, or negotiate with better-resourced actors. The long-horizon question is whether these gains become durable capacities of participants or remain contingent on interfaces whose governance they cannot influence.

The generative-participation reserve defined in Section 18.14 is therefore itself dynamic. Educational pathways, rights, institutions, archives, public spaces, community organizations, technical tools, and cultural practices require renewal. A reserve can expand when new participants gain effective entry, when institutions create new channels for co-design, or when automation releases time for inquiry and care. It can contract when participation becomes symbolic, when independent institutions disappear, or when economic insecurity prevents supported access from becoming sustained involvement.

Intergenerational renewal is especially important. A society can preserve participation for currently established actors while weakening entry for those who come later. Professional bodies can retain senior expertise while junior pathways disappear. Community institutions can retain nominal membership while young participants lack time, resources, or meaningful roles. Public decision systems can preserve current representatives while future participants inherit infrastructures whose design is difficult to contest. Long-horizon participation therefore includes the reproduction of entry routes, not only the protection of incumbent participants.

Heterogeneous subjecthood adds another dimension. Section 18.15 showed that participation rights, welfare standing, delegated agency, collective representation, and ecological affectedness are different forms of standing. Their trajectories can diverge. Artificial agents may acquire more delegated operational authority without acquiring wider normative standing. Human participants may retain formal standing while losing practical influence. Non-human affected positions may become more visible through sensing and modeling while remaining dependent on institutional representation. Participation analysis should record which dimension is changing rather than treating increased system inclusion as a uniform expansion of standing.

Proposition 18.266 (Participation-renewal condition). *A participation trajectory is more generatively sustainable when consequential pathways remain accessible to current participants and institutions continue to reproduce the capabilities, roles, resources, and entry routes through which future participants can shape knowledge, decisions, institutions, care, community, and culture.*

Participation-renewal analysis also guards against assigning humans a ceremonial residual role. An order can reserve nominal human approval while substantive framing, evidence selection, option generation, and implementation are effectively settled elsewhere. The long-horizon criterion concerns whether persons and human-governed collectives can still alter the architecture within which decisions are formed, including the rules governing artificial agents and the mediation of heterogeneous values.

18.16.6 Knowledge Trajectories

Knowledge trajectories connect Chapter 17 to the long-horizon AI problem. Knowledge is generated, verified, preserved, transmitted, institutionalized, forgotten, reinterpreted, and converted into practical capacity through historically changing relations. Artificial systems can accelerate several of these processes while reorganizing the infrastructure on which they depend. The relevant long-horizon object is therefore the evolving capacity of a society, organization, or community to know, verify, remember, reinterpret, and generate questions under changing technical mediation.

A first distinction separates knowledge access from knowledge regeneration. AI can provide rapid access to explanations, summaries, translations, code, analyses, and candidate solutions. Such access can expand epistemic capability substantially. Regenerative knowledge capacity additionally requires methods, records, institutions, skilled communities, provenance, contestation, and educational practices through which claims can be reconstructed, challenged, extended, or replaced. Access can remain high while regenerative capacity becomes concentrated elsewhere.

Verification has its own trajectory. When machine-generated outputs become abundant, the scarce component can shift toward trusted evidence, provenance, domain judgment, and the capacity to inspect how a claim was formed. Section 18.10 treated this as an epistemic-dependence problem. Over longer periods, verification institutions themselves can change: journals, courts, public agencies, professional bodies, schools, laboratories, archives, and media organizations can adopt new standards or lose resources as users rely more heavily on direct model interfaces. The reliability of future knowledge therefore depends partly on the institutions that maintain verification practices during the transition.

Preservation is equally important. AI systems can make large archives searchable and can assist migration, classification, and reconstruction. They can also produce fragile dependence when knowledge is stored in proprietary representations, when model versions disappear, or when generated summaries displace access to underlying records. Section 17.13 emphasized preservation and historical re-epistemization. Long-horizon AI order should preserve enough source material, metadata, model and policy documentation, and institutional memory that later observers can revisit earlier interpretations with improved knowledge.

Question formation and orientation form another trajectory. Section 18.12 argued that abundance of candidate problems and solutions increases the importance of judgment about which questions deserve attention. If research and public reasoning become strongly mediated by a small set of systems, their categories, retrieval structures, evaluation procedures, and optimization targets can influence which questions are salient. This influence need not be centrally planned to become historically consequential. Repeated mediation can create attention paths that reinforce some research programs, representations, or problem framings while making others harder to sustain.

Epistemic plurality can therefore function as a generative resource. Different institutions, disciplines, languages, methods, communities, and model ecosystems can preserve alternative representations of the same field. Plurality can create duplication and coordination cost, yet it can also support error detection, conceptual innovation, translation, and recovery when one epistemic pathway fails. The appropriate level of plurality varies by domain; the long-horizon issue is whether standardization removes distinctions whose later value cannot yet be known.

Human learning remains part of this trajectory even when artificial systems exceed human performance in many tasks. Learning changes the learner's capacity to judge, formulate questions, participate in institutions, understand evidence, and create relations. A system that supplies correct answers can support learning or substitute for it depending on how the interaction is organized. Educational and professional institutions therefore shape whether epistemic abundance becomes expanded human capability, deeper dependence, or some mixture of both.

Proposition 18.267 (Epistemic-regeneration condition). *A knowledge trajectory is more robust when expanded AI-mediated access is coupled with preservation of provenance, verification capacity, reconstructible records, plural interpretive pathways, question-forming institutions, and learning processes through which relevant knowledge can continue to be challenged and regenerated.*

This condition does not require duplication of machine capability by humans. It requires an epistemic ecology able to determine when reliance is warranted, to preserve histories of knowledge formation, to maintain alternative routes of inquiry where they matter, and to develop new criteria when earlier representations become inadequate. Such an ecology supports the institutional self-revision described in Subsection 18.16.3 because governance cannot revise what it can neither understand nor reconstruct.

18.16.7 Future-Possibility Openness

The six trajectories converge on a question of future possibility. Long-horizon governance cannot preserve a fixed set of future options because future technologies, values, institutions, ecological conditions, subject configurations, and problems are only partly knowable in advance. Chapter 15 therefore treated future histories through accessibility, branching, path dependence, intervention, and changing admissibility rather than as a pre-existing menu of choices. In the AI context, openness concerns the practical capacity of an economic order to continue generating, recognizing, and institutionalizing alternatives as conditions change.

Future openness should be distinguished from maximizing the number of options. Some options can be harmful, mutually incompatible, prohibitively costly, or dependent on injustice. Rights, safety requirements, ecological constraints, and collective commitments can appropriately close pathways. An order also requires standards and coordination; permanent refusal to commit can prevent infrastructure, trust, investment, or collective action. The relevant criterion is whether closure is proportionate to its justification and whether the order preserves sufficient capacities for later revision where uncertainty remains material.

Definition 18.268 (Future-possibility openness). *Future-possibility openness* is a property of an economic order in which relevant subjects and institutions retain practical capacities to recognize changing conditions, generate or recover materially different alternatives, evaluate them through revisable subject-value mediation, and reorganize consequential relations when inherited arrangements become inadequate.

The definition links openness to capability and institution rather than to abstract possibility alone. A technically conceivable alternative is weakly relevant if no actor can finance it, understand it, organize around it, obtain necessary rights, reconstruct required knowledge, or access compatible infrastructure. Likewise, formal permission has limited practical significance when dependency, concentration, or lost capability makes an alternative unreachable. Future-possibility openness therefore depends on generative accessibility in the sense developed in Section 15.6.

Several resources can support openness. Modular and interoperable infrastructure can lower the cost of recombination. Public and commons capacities can preserve alternatives outside narrow market incentives. Archives and provenance can make prior decisions reconstructible. Education and research institutions can generate new capabilities and questions. Rights of contestation, exit, and organization can permit affected subjects to initiate change. Diverse organizational forms can preserve experiments that would disappear under one dominant architecture. Re-

versibility can allow learning before commitments become difficult to undo.

Heterogeneous value makes openness especially important. Section 18.15 rejected the assumption that one scalar representation exhausts the values of heterogeneous subjects. The future adds another layer of incompleteness: later participants can inherit values, identities, technologies, and problems that present institutions do not anticipate. A long-horizon order should therefore be cautious about encoding present evaluative settlements so deeply into infrastructure that future participants cannot revisit them. This caution does not grant hypothetical future preferences automatic priority over present needs. It treats future revisability as one relevant value among others.

Openness can also have distributional structure. A system may contain many alternatives in aggregate while particular communities, regions, professions, or social groups have little access to them. Future-option analysis should therefore ask who can exercise alternative-forming capacity, who bears the costs of transition, and whose infrastructures are preserved. Concentrated option ownership can create a nominally innovative order in which only a small number of actors can materially redirect the trajectory.

The same issue appears at the level of artificial systems. A diverse ecosystem of models can still depend on one compute layer, one data infrastructure, one identity system, or one procurement channel. Apparent plurality at one layer can coexist with concentration at another. Future-possibility openness therefore requires multiscale diagnosis of bottlenecks rather than counting visible applications or providers.

Proposition 18.269 (Open-future generativity). *A human–AI order has a stronger future-possibility openness when its current arrangements preserve distributed capacities for learning, recombination, contestation, institution building, infrastructural substitution, and value re-articulation sufficient to generate materially different responses to later conditions that cannot be specified completely in the present.*

Proposition 18.269 extends the anti-foreclosure criterion of Section 18.14. Generative foreclosure identifies cases in which alternative-forming capacity is degraded. Future-possibility openness identifies the positive institutional property that allows alternatives to continue emerging. The concepts are related without being simple opposites: an order can avoid severe foreclosure while still having a narrow generative ecology, and it can preserve substantial openness in some domains while closing others deliberately.

18.16.8 Closure Discipline and Revisable Order

Economic order requires closure. Budgets must be allocated, standards selected, systems deployed, rights defined, infrastructure built, and decisions implemented. Long-horizon governance therefore cannot be organized around indefinite postponement. The central problem is the discipline under which temporary, local, or durable closures are made when AI capability, affected subject positions, and relevant value structures remain capable of changing.

A closure becomes historically important when it alters later transition structure. Technical standards can determine which systems interoperate. Procurement can

shape vendor ecosystems. Educational policy can shape future skill distributions. Infrastructure investment can privilege particular architectures. Data regimes can determine which actors can train or audit systems. Liability rules can influence which applications are developed. Organizational restructuring can move expertise outside an institution. Each decision can be locally rational while also increasing the probability that one path becomes self-reinforcing.

GRE uses *premature closure* for a narrower condition than ordinary commitment. Prematurity concerns a mismatch between the strength or durability of closure and the available justification for fixing the relevant part of the order. This mismatch can arise because uncertainty remains high, affected positions are weakly represented, switching costs are accumulating, alternative-forming capacity is being removed, or revision mechanisms are too weak for the consequences of error.

Definition 18.270 (Premature order closure). *Premature order closure* is a historically consequential commitment that substantially narrows later practical alternatives or alternative-forming capacity before the evidential, institutional, normative, or coordination basis for such durable narrowing is sufficiently established relative to the stakes, reversibility, and distribution of consequences.

Definition 18.270 is deliberately conditional. Some high-stakes domains can justify strong closure even under uncertainty, especially where rights, safety, catastrophic risk, or ecological irreversibility are involved. Other domains benefit from experimentation and plural pathways. The diagnosis depends on what is being closed, for whom, for how long, through which mechanism, with which consequences, and with what capacity for correction.

Premature closure differs from generative foreclosure. Premature closure describes the timing and justification of a commitment relative to uncertainty and reversibility. Generative foreclosure describes degradation of the mechanisms through which future alternatives could be produced. A premature closure can generate foreclosure when it removes capabilities, institutions, or infrastructure needed for alternatives. It can also remain reversible and therefore never become foreclosure. Conversely, generative foreclosure can emerge gradually through many individually modest decisions without one identifiable premature commitment.

Closure discipline therefore requires explicit temporal design. Institutions can specify review intervals, portability requirements, interoperability standards, archival obligations, transition plans, capability-retention requirements, appeal routes, sunset or renewal procedures where appropriate, and triggers for deeper reassessment when the technical or social environment changes. The form should match the domain. A safety-critical infrastructure may require stronger continuity and certification; an experimental educational tool may justify shorter authorization cycles; a public knowledge archive may warrant especially strong preservation and portability requirements.

Reversibility is only one component. Section 18.13 defined a governance reversibility reserve because correction becomes harder as dependence and complementary investment deepen. Some commitments are physically or institutionally difficult to reverse, yet they can remain governable if their scope is bounded, alternatives are preserved elsewhere, and later generations retain capacities to create new path-

ways. Conversely, a technically reversible software choice can become practically entrenched through data, skills, habits, standards, and network effects. Closure analysis should therefore consider the whole coupled trajectory rather than a nominal undo function.

Near-critical conditions increase the importance of this discipline. Section 16.15 argued that governance should change when defensible representations indicate heightened sensitivity, amplified response, or increased accessibility of qualitative transition. In an AI-mediated order, rapid capability change, concentrated infrastructure, or cascading institutional dependence can create situations in which a small design choice produces large downstream effects. Stronger monitoring, staged intervention, plural modeling, and preservation of rollback or alternative pathways can be appropriate where transition uncertainty is materially elevated.

Responsibility for closure should also remain identifiable. Artificial systems can recommend standards, optimize allocations, or rank institutional options, yet the authority to make a durable closure derives from a governance arrangement. Section 18.15 treated subject–value mediation interfaces as the structures through which standing and value enter decision. Long-horizon closure should therefore record who authorized the commitment, which representations were used, which subject–value remainders remained, what future effects were considered, and which revision pathway was retained.

Proposition 18.271 (Revisable-order condition). *A long-horizon human–AI order is more governable when durable commitments are accompanied, in proportion to their stakes and path dependence, by preserved knowledge, identifiable responsibility, reviewable justification, capability for institutional learning, and practical mechanisms through which materially changed conditions can support revision, replacement, or reauthorization.*

Proposition 18.271 does not imply continual institutional change. Stability can itself be generative by enabling trust, planning, specialization, and long-term investment. The proposition concerns the difference between stable order and closed order. Stable institutions can retain capacities for self-revision; closed institutions can become unable to respond even when their original conditions have disappeared.

The long-horizon architecture developed in this section can now be summarized through the coupled-trajectory condition. Dependency should be evaluated through its reversibility and regenerative alternatives; capability through its pathways of renewal; institutions through their capacity for self-revision; labor through transition, learning, and participation; participation through consequentiality and intergenerational entry; knowledge through verification, preservation, and regeneration. Future-possibility openness then asks whether these trajectories jointly preserve capacities for later alternative formation, while closure discipline asks how present commitments can remain proportionate to uncertainty, path dependence, and the consequences of being wrong.

This synthesis completes the chapter's general architecture of AI asymmetry. It does not determine a single institutional design for education, research, work, development, communities, ecology, or public administration because the relevant subjects, values, infrastructures, risks, and temporal mechanisms differ across domains.

Section 18.17 therefore applies the chapter's analytical distinctions to those domain interfaces, identifying which parts of the framework become especially consequential in each setting while preserving the need for domain-specific evidence and institutional judgment.

18.17 Domain Implications of Artificial Intelligence

The preceding sections developed a general account of artificial intelligence under radical capability asymmetry through productive capacity, power conversion, labor, subjecthood, ownership, surplus, redistribution, relational dependence, epistemic mediation, governance, generative participation, heterogeneous value, and long-horizon order. The role of the present section is to specify how that architecture changes when it enters domains whose objects, institutions, values, histories, and failure modes differ materially. Its objective is therefore narrower than a complete theory of education, research, work, development, communities, ecology, or public institutions. It identifies the AI-sensitive analytical interfaces that deserve attention in each domain and clarifies which distinctions from Chapter 18 should remain visible during later domain inquiry. The discussion proceeds through seven domain interfaces and concludes with a comparative synthesis. Its method is translational and diagnostic: the chapter-level framework is carried into each domain only to the degree that the domain preserves the relevant relations, while domain-specific evidence, concepts, and institutional knowledge remain necessary for substantive conclusions.

A domain implication in this sense is a bounded translation of the chapter-level architecture into a specified setting. Artificial intelligence can enter a domain as infrastructure, tool, delegated agent, representational system, gatekeeping mechanism, source of productive capacity, source of epistemic dependence, or component of institutional decision. The economic significance of that entry depends on which subjects gain or lose capabilities, which dependencies deepen or become reversible, which values are represented, which forms of participation remain consequential, which infrastructures become concentrated, and which future pathways remain available. The same technical capability can therefore have different generative consequences in a classroom, laboratory, workplace, local community, ecological monitoring system, or public agency.

Definition 18.272 (AI-domain interface). An *AI-domain interface* is a historically situated configuration in which artificial capabilities, infrastructures, representations, or delegated operations enter a domain-specific set of subjects, relations, values, institutions, dependencies, and temporal pathways, thereby altering the conditions under which domain-relevant goods, capabilities, decisions, and future alternatives are generated.

Definition 18.272 keeps the unit of analysis relational. A domain is represented as a field whose technical, institutional, human, and historical components jointly shape the consequences of AI entry. The interface includes the institutions that procure or govern systems, the human and collective subjects who depend on them, the infrastructures and ownership arrangements that make them available, the represen-

tations through which domain phenomena become legible, and the historical pathways through which these arrangements acquire persistence. Section 18.3 therefore remains relevant whenever capability asymmetry becomes power through dependency or control, while Sections 18.14–18.16 remain relevant whenever present technical gains affect future participation, heterogeneous value, or alternative-forming capacity.

Table 18.17 summarizes the interfaces developed below. The table is intentionally diagnostic. It identifies the generative object whose trajectory deserves particular attention in each domain and the associated AI-sensitive problem. Domains may contain several objectives and additional institutional or normative concerns beyond those summarized here.

18.17.1 Education and Generative Capability

Education is a direct site of capability formation and therefore provides a particularly clear test of the distinction between immediate performance and regenerative capacity developed in Section 18.16. Artificial systems can expand access to explanation, translation, practice, feedback, simulation, examples, and individualized assistance. These functions can reduce barriers created by geography, language, cost, disability, scarce instructional time, or uneven prior preparation. Their economic relevance extends beyond learning efficiency because education shapes later access to work, research, public participation, cultural production, and institutional membership.

The central domain question concerns what kind of capability an educational arrangement generates. A learner who can complete a task with an AI system may possess a valuable extended capability even when the same task cannot be completed unaided. Extended capability can be economically and intellectually significant. Educational analysis nevertheless needs a second question: whether the relation also develops capacities for interpretation, verification, transfer, problem formation, judgment, and learning under changed tools or absent support. Section 18.10 showed that access and epistemic regeneration can diverge; education is one of the principal mechanisms through which that divergence is either widened or repaired.

This distinction is compatible with extensive use of assisted performance. Many human capabilities have long depended on books, teachers, laboratories, calculators, institutions, and collaborative communities. The relevant issue is the structure of dependence. An educational dependence can be generative when the learner gains access to methods, concepts, communities, and practices that later enlarge independent and collective capability. It becomes more fragile when successful performance depends on an interface whose outputs cannot be evaluated, whose categories determine the learner's problem space, or whose continued availability is outside the learner's or institution's practical control.

Judgment therefore becomes part of educational infrastructure. Section 18.12 emphasized research orientation under symbolic abundance; the same architecture applies earlier in capability formation. When answers, explanations, images, code, and candidate arguments become abundant, learners still require practices for deciding which questions deserve attention, which sources warrant trust, which distinctions matter, which representations are adequate, and when an apparently fluent answer

Table 18.17: Diagnostic map of AI-domain interfaces in Chapter 18.

Domain	AI-mediated leverage	Generative object of attention	Characteristic diagnostic
Education	Tutoring, assessment, translation, explanation, content generation	Learning capability, judgment, curiosity, peer and teacher relations	Whether assistance expands durable capability and preserves routes to independent inquiry
Research	Search, synthesis, modeling, coding, hypothesis and artifact generation	Epistemic regeneration, verification, orientation, research communities	Whether abundance of candidate outputs is accompanied by provenance, plural inquiry, and question-forming capacity
Work	Task automation, coordination, evaluation, scheduling, design support	Livelihood, capability formation, membership, contribution, bargaining capacity	Whether productivity gains preserve developmental pathways and consequential organizational participation
Development	Translation, planning, targeting, monitoring, service coordination	Local capability, institutional capacity, infrastructure, autonomous adaptation	Whether access converts into locally reproducible capability without rigid external dependency
Communities	Communication, moderation, discovery, documentation, coordination	Trust, reciprocity, collective memory, local institutions, commons	Whether technical mediation strengthens collective capacity while preserving community-governed relations
Ecology	Sensing, prediction, simulation, classification, resource optimization	Ecological continuity, represented affectedness, regeneration, intergenerational option space	Whether improved representation supports stewardship while respecting uncertainty, irreversibility, and non-human affected positions
Public institutions	Decision support, case processing, service delivery, forecasting, administrative coordination	Public capacity, responsibility, contestability, institutional learning, public reason	Whether delegated technical capacity remains embedded in accountable and revisable public authority

should be challenged. Such practices include disciplinary judgment, historical understanding, aesthetic and interpretive judgment where relevant, and the capacity to recognize uncertainty or missing context.

Teachers and peers remain economically relevant within this architecture even where artificial tutoring becomes highly capable. Their role can include evaluation, motivation, care, social recognition, conflict mediation, exposure to heterogeneous perspectives, modeling of disciplinary practice, and participation in a learning com-

munity. These relations can also change under AI. Teachers may gain time for high-value interaction when routine explanation or administration is assisted; they may also lose discretion when curricula, assessment, or monitoring become externally standardized through technical platforms. A domain analysis should therefore examine how AI redistributes instructional labor and authority and situate the technology within the wider learning relation.

Educational institutions also reproduce entry pathways. If advanced assistance allows experienced learners to progress faster while foundational teaching institutions weaken, present performance gains can coexist with declining capacity to form future cohorts. Conversely, lower-cost tutoring and translation can enlarge entry where teachers and institutions use them to reach previously excluded learners. The long-horizon educational question is therefore intergenerational: whether a system maintains enough pedagogical, social, and institutional capacity to reproduce learners who can later modify the knowledge and tools they inherit.

Proposition 18.273 (Educational generativity condition). *An AI-mediated educational arrangement is more generative when expanded access to assistance is coupled with durable formation of interpretive, verificatory, problem-forming, collaborative, and domain-specific capabilities, together with institutions and learning relations through which later learners can continue to acquire and revise those capabilities.*

Proposition 18.273 functions as a domain diagnostic; pedagogical prescriptions remain specific to educational purpose and context. Different subjects, ages, disciplines, and educational purposes can require different mixtures of automation, direct instruction, practice, social learning, and independent work. The proposition identifies the capability trajectory that should remain visible when evaluating those arrangements.

18.17.2 Research and Epistemic Regeneration

Research provides a second interface because artificial intelligence can act across several stages of knowledge generation: retrieval, translation, coding, modeling, simulation, literature synthesis, experimental design, data analysis, drafting, and generation of candidate hypotheses or explanations. The resulting increase in symbolic and computational abundance can expand the feasible research space. It can also reorganize the scarce resources within that space. Section 18.11 located scarcity increasingly in provenance, verification, trust, attention, and orientation when symbolic output becomes abundant; Section 18.12 then emphasized the formation and selection of research problems.

The first domain implication is that research productivity should be separated from epistemic regeneration. A laboratory or scholar can produce more artifacts with AI assistance while becoming more dependent on external models, proprietary data, inaccessible computational infrastructure, or procedures that are difficult to reconstruct. Such dependence may be reasonable where the benefit is large and alternatives are unnecessary, yet it changes the conditions under which claims can later be checked, extended, or reinterpreted. Research evaluation should therefore record the infrastructures and verification pathways that stand behind apparent productivity gains.

A second implication concerns orientation. Artificial systems can generate large numbers of plausible questions, models, proofs, designs, or explanations. This expands candidate space while increasing the importance of judgments about relevance, tractability, significance, novelty, beauty, social importance, and evidential adequacy. These judgments are historically and institutionally formed. They are influenced by disciplines, funding systems, archives, professional communities, language, and prior exemplars. Research mediated through a narrow technical infrastructure can therefore acquire an orientation dependence even when researchers retain formal freedom to choose topics.

Epistemic plurality becomes especially important at this interface. Different methods, disciplines, model families, languages, laboratories, theoretical traditions, and communities can preserve distinct representations of a problem. Some duplication may appear inefficient from a short-run production perspective, yet plurality can support error discovery, conceptual innovation, resilience, and recovery from shared assumptions. A research system that centralizes generation while preserving independent verification may therefore have a different long-horizon profile from one that centralizes both generation and judgment.

Research communities also reproduce capability through apprenticeship and participation. Junior researchers learn by performing tasks that may later be automated: literature search, coding, data cleaning, replication, derivation, experimental preparation, and drafting. Removing routine work can free attention for higher-level inquiry, while removing developmental steps without replacement can weaken the route through which researchers acquire tacit and technical competence. The labor-trajectory analysis of Section 18.16 thus applies inside research institutions as well as commercial organizations.

Preservation provides a further requirement. AI-assisted research can produce models, code, datasets, transformations, prompts, generated artifacts, and intermediate representations that become difficult to reconstruct if systems change. A generative research order therefore benefits from preservation of sources, provenance, methods, model and software context where feasible, and enough institutional memory to permit later re-examination. The relevant standard varies by discipline and risk, yet the underlying concern is common: later inquiry should not depend entirely on an unavailable technical moment.

Proposition 18.274 (Epistemic-regeneration condition). *An AI-mediated research system is more epistemically generative when increases in search, synthesis, modeling, and artifact production are accompanied by reproducible or inspectable evidential pathways, plural sources of orientation, preserved research memory, and communities capable of verifying, criticizing, and reformulating the questions and methods through which knowledge is generated.*

The proposition keeps AI assistance within the broader epistemic economy developed in Chapter 17. It leaves open which technical and institutional arrangements satisfy the condition in particular fields and therefore prepares the questions for detailed domain analysis.

18.17.3 Work and Organizational Participation

Work is the domain in which artificial productive capacity most visibly encounters livelihood, organizational membership, bargaining relations, identity, learning, and contribution. Sections 18.4 and 18.7 separated task substitution from employment and traced AI-generated surplus through generation, capture, allocation, investment, and recirculation. The domain implication is that the economic effect of AI at work should be analyzed through the organization of tasks and relations together, because the same productivity gain can support different trajectories of income, capability, authority, and participation.

Task decomposition is a useful starting point. Occupations combine activities with different technical requirements, social functions, legal responsibilities, tacit knowledge, and developmental roles. AI can automate selected tasks, augment others, create new coordination burdens, or change the relative value of human judgment and relational work. Organizational response then determines whether workers experience the change as displacement, intensification, capability extension, role redesign, or access to new forms of contribution. Aggregate productivity measures alone leave these relational outcomes underdetermined.

Capability formation deserves particular attention. Many workplaces have historically functioned as sites where people acquire judgment through supervised practice, encounter difficult cases, build professional networks, and move from peripheral to central participation. If entry-level tasks become automated, organizations can gain efficiency while weakening a developmental pathway. Alternative pathways can be designed through simulation, rotation, supervised AI use, apprenticeship, or newly defined roles, but their effectiveness is an empirical and institutional question. The long-horizon concern is the reproduction of expertise across changing task bundles.

Organizational membership also matters. Employment can provide income, but it can also provide status, association, access to information, shared purpose, bargaining structures, and a recognized position from which decisions can be influenced. An AI-mediated organization can retain workers while shifting consequential authority into technical systems or management units that control them. Performance evaluation, scheduling, hiring, workflow allocation, and strategic planning can therefore alter power relations even when headcount is stable. Section 18.3 supplies the relevant conversion question: which asymmetries become power through control of information, infrastructure, access, or organizational dependency?

Surplus recirculation links firm-level change to wider economic order. Productivity gains can finance lower prices, higher wages, profits, investment, reduced working time, public revenue, training, new services, or combinations of these. Their generative effect depends on where resulting resources flow and which capabilities they reproduce. Redistribution after displacement can secure material conditions, as Section 18.8 emphasized, while organizational design can additionally preserve participation, bargaining, and learning before displacement becomes the dominant mechanism of adjustment.

Care and relational labor make the domain especially heterogeneous. Some work produces goods that can be evaluated largely through output characteristics; other work partly consists in attention, trust, embodied presence, recognition, responsibil-

ity, or durable relationship. AI can support such work through documentation, translation, scheduling, decision support, or accessibility. The value of the relation may nevertheless depend on who participates and how responsibility is carried. Domain analysis should therefore distinguish functional substitution from relational substitution, as developed in Section 18.9.

Proposition 18.275 (Organizational participation condition). *An AI-mediated work arrangement is more generatively sustainable when productivity gains are evaluated together with livelihood security, capability formation, bargaining relations, routes of occupational entry, distribution of decision authority, and the continued availability of consequential forms of organizational contribution.*

This condition permits substantial change in jobs and organizational forms. It identifies the dimensions through which work contributes to later capability and participation, allowing domain-specific analysis to distinguish productive transformation from erosion of the pathways through which future contributors are formed.

18.17.4 Development and Capability Infrastructure

Development and humanitarian settings expose the difference between access to an advanced capability and possession of the conditions needed to reproduce, govern, adapt, and contest that capability locally. Artificial intelligence can support translation, diagnosis, planning, logistics, education, agricultural advice, financial services, administrative processing, hazard analysis, and coordination across scarce professional resources. These possibilities can be especially consequential where expertise or infrastructure is unevenly distributed. Their generative value depends, however, on how technical access interacts with local institutions, languages, data, material infrastructure, professional communities, and existing dependency relations.

A transfer-oriented account can treat an AI service as a resource delivered to a recipient population or organization. GRE adds a conversion question. The same nominal access can become very different effective capability depending on connectivity, electricity, device access, language support, data quality, institutional trust, legal authority, professional interpretation, maintenance capacity, and the ability to adapt the system to local purposes. Section 18.2 therefore remains central: capability is typed and relational, and a high-capability system produces different realized capacities across different configurations.

Dependency requires corresponding attention. A service can improve present welfare while creating reliance on external providers for model access, updates, identity systems, cloud infrastructure, proprietary data, or technical expertise. Such reliance may be acceptable or even advantageous when it is transparent and stable. Long-horizon analysis nevertheless asks whether local actors retain meaningful options if prices, policies, models, geopolitical conditions, or organizational priorities change. The dependency-revisability condition developed in Section 18.16 becomes a development question about portability, interoperability, training, local institutional competence, alternative channels, and bargaining position.

Participation changes the quality of the interface. Local actors can appear in a project as data sources, beneficiaries, users, implementers, evaluators, co-designers, owners, regulators, or institutional partners. These positions carry different capaci-

ties to shape the system and its purposes. Consultation and generative participation should therefore be recorded separately. Section 18.14 suggests a stronger diagnostic: whether affected communities and institutions can influence problem definition, adaptation, evaluation, and future redesign, including stages that precede presentation of a technical solution.

Language and knowledge representation are particularly important. Systems trained predominantly on externally produced materials can increase access to global information while underrepresenting local categories, histories, legal practices, ecological knowledge, or linguistic distinctions. Translation can expand participation, yet it can also compress meanings whose relevance becomes visible only within local relations. The heterogeneous-value architecture of Section 18.15 therefore applies to development as an issue of institutional mediation that includes cultural sensitivity and extends to representation, authority, and value conversion.

Humanitarian settings add urgency and asymmetric vulnerability. Rapid coordination can save time where information is incomplete and resources are scarce, yet errors can affect persons with limited capacity to exit or contest the system. Institutional design in such contexts may require stronger attention to fallback procedures, human review, provenance, responsibility, and continuity when technical infrastructure fails. The appropriate design depends on the service and risk; the general GRE contribution is to keep dependency, conversion, and participation visible alongside immediate functional benefit.

Proposition 18.276 (Local capability-conversion condition). *An AI-enabled development intervention has stronger generative potential when external technical capacity is converted into locally usable and revisable capability through supporting infrastructure, institutional competence, language and knowledge mediation, participatory adaptation, and practical options for continuity when external conditions change.*

The proposition treats local capability as an evolving process with graduated conditions. It therefore allows external dependence, partnership, and specialization to remain part of development while making their temporal and institutional terms explicit.

18.17.5 Communities and Relational Capacity

Communities provide a domain in which economic generation often depends on relations that are only partially visible in prices or formal organizations: trust, reciprocity, shared memory, informal care, common spaces, language, mutual recognition, local knowledge, volunteer activity, and collective rules. Artificial intelligence can support communities through translation, documentation, moderation, discovery, coordination, accessibility, archival work, fundraising, and administrative assistance. These functions can reduce organizational burdens and widen participation. Their effects depend on whether technical mediation strengthens community capacity or relocates consequential coordination into external infrastructures.

The community interface therefore differs from an individual-user interface. A tool that benefits many individual members can still change collective relations. Personalized recommendation can improve access to relevant information while fragmenting shared attention. Automated moderation can reduce harmful interaction

while moving rule interpretation away from locally accountable processes. Generative systems can help preserve oral histories or local languages while also increasing the volume of synthetic cultural material through which authentic provenance becomes harder to establish. Section 18.11 is relevant because symbolic abundance changes the conditions under which community memory and cultural recognition are maintained.

Collective subjecthood adds another layer. Section 18.15 emphasized that a collective can possess joint capacity and institutional continuity without being internally homogeneous. AI tools used by a community organization can amplify the voice of those who control configuration, data access, or organizational accounts. A nominally collective output may therefore represent a subset of members, an inherited institutional procedure, or a model-mediated synthesis that differs from an uncontested community preference. Governance should keep representation visible and identify whose positions are carried by the collective output.

Commons provide a concrete economic setting for these relations. Shared informational, cultural, ecological, or physical resources require rules about access, contribution, maintenance, monitoring, and conflict resolution. AI can lower the cost of some of these functions, but it can also create new dependencies on platforms that mediate access to the commons or extract data and attention from communal activity. Ownership and access analysis from Section 18.6 therefore extends to community infrastructure: who controls the technical layer through which collective resources are discovered, maintained, represented, or governed?

Relational capacity also has a temporal dimension. Trust and reciprocity accumulate through repeated interaction and can be difficult to reconstruct after institutional displacement. A technically efficient substitution for a community process may therefore have delayed effects if it removes occasions through which members previously learned one another's needs, negotiated norms, or developed shared competence. The relevant criterion is the relational function carried by the process. Automation can remain extensive where those functions are reproduced while the community retains future capacity to coordinate itself.

Proposition 18.277 (Community relational-capacity condition). *An AI-mediated community arrangement is more generative when technical assistance enlarges members' ability to coordinate, preserve knowledge, care, deliberate, and maintain shared resources while the community retains meaningful capacity to govern the rules, representations, and infrastructures through which those relations are mediated.*

The condition is compatible with extensive use of external systems. Its focus is whether technological mediation becomes a resource for collective capacity or a substitute for the relations through which collective capacity is reproduced.

18.17.6 Ecology and Represented Affectedness

Ecology expands the AI-domain interface beyond conventional human and organizational subjects. Artificial intelligence can improve sensing, classification, forecasting, simulation, resource management, conservation planning, pollution detection, energy coordination, and analysis of complex environmental systems. These capabilities can increase the visibility of ecological processes that are otherwise difficult

to observe. Their use also illustrates the representational problem developed in Section 18.15: many ecologically affected beings, systems, and future conditions do not enter economic decision through ordinary preference expression or contractual agency.

Ecological representation therefore requires an institutional interface. Measurements, models, legal categories, stewardship practices, scientific institutions, local knowledge, and public deliberation convert ecological affectedness into decision-relevant form. AI can strengthen this process by processing complex data and exploring scenarios. It can also narrow the represented field if optimization targets capture only the dimensions that are easy to quantify or if model uncertainty is hidden behind precise outputs. The economic question concerns how representation alters allocation, protection, and future possibility alongside changes in predictive accuracy.

Irreversibility makes the temporal architecture particularly important. Environmental decisions can alter habitats, species relations, resource stocks, pollution burdens, and climate-relevant systems over periods longer than the institutions or models that authorize them. Section 18.16 therefore applies with heightened force where later correction is physically costly or impossible. Future-possibility openness in ecological settings includes preservation of regenerative processes, option space, monitoring capacity, and the knowledge required to recognize changing conditions.

Criticality also matters. Some ecological systems can exhibit nonlinear responses, thresholds, regime shifts, or amplified sensitivity. GRE requires defensible representation and evidence appropriate to the system under study before treating critical behavior as analytically relevant; Section 16.15 supplies this discipline. Where empirical and domain-specific analysis indicates materially elevated transition risk, AI-assisted prediction can support monitoring and scenario analysis, while governance can place greater weight on staged intervention, redundancy, reversibility where available, and protection against irreversible loss.

The heterogeneous-value problem is equally direct. Ecological decisions can involve human welfare, non-human welfare where relevant, biodiversity, cultural attachment, livelihood, energy access, ecological integrity, intergenerational interest, and scientific or option value. Some of these dimensions can be monetized for specified purposes; others can retain remainders that should remain visible after conversion. AI optimization leaves that plurality within the institutional and normative mediation problem because the construction of a common objective function already selects and transforms value dimensions.

Artificial systems also possess material footprints through computation, hardware, energy, water, extraction, logistics, and disposal. Domain analysis therefore should include the resource and infrastructure conditions of the AI system itself when they are materially relevant. A system that improves one ecological process can impose costs elsewhere in the coupled configuration. The appropriate boundary depends on the inquiry, but boundary choice should be explicit enough to prevent local optimization from being mistaken for system-wide improvement.

Proposition 18.278 (Ecological representation and regeneration condition). *An AI-mediated ecological arrangement is more generatively adequate when ecological affect-*

edness is represented through plural and inspectable evidential channels, material system boundaries are stated, relevant value remainders remain visible, and decisions preserve monitoring, regenerative capacity, and future options in proportion to ecological uncertainty and irreversibility.

The proposition remains agnostic among competing theories of ecological value. It specifies the informational, temporal, and institutional conditions under which heterogeneous ecological value can remain governable within an AI-mediated economic order.

18.17.7 Public Institutions and Revisable Authority

Public institutions combine administrative capacity with legally or politically constituted authority. Artificial intelligence can assist case processing, translation, service delivery, forecasting, document analysis, fraud detection, resource allocation, infrastructure management, regulatory monitoring, and policy analysis. These functions can increase speed, consistency, accessibility, or analytical reach. The domain implication is that public technical capacity should remain distinguishable from public authority: an artificial system can perform or recommend operations while the legitimacy, responsibility, and revisability of public action remain properties of an institutional arrangement.

Section 18.3 is especially important here because infrastructural and epistemic dependence can convert technical asymmetry into public power indirectly. A public agency can formally retain authority while losing practical capacity to understand, modify, procure alternatives to, or operate without a technical system. Vendor concentration, proprietary data structures, specialized cloud infrastructure, and scarce expertise can therefore affect public bargaining position and continuity. Procurement is consequently part of governance architecture with technical, financial, infrastructural, and institutional dimensions.

Contestability gives this architecture a citizen-facing form. Persons affected by public decisions may need to understand which institution acted, which evidence was relevant, which rules governed the action, and where review or appeal can occur. AI can assist explanation and case handling, while institutional adequacy can require more than a model-generated explanation. Public reasons may require legal relevance, evidential provenance, consistency with mandate, and the possibility of challenge by the affected person. The representational governance conditions developed in Section 18.13 therefore acquire domain-specific procedural content.

Responsibility should remain traceable across delegation. A decision process may involve software developers, model providers, data systems, civil servants, contracted operators, supervisors, agencies, courts, and elected or otherwise authorized bodies. Distributed participation increases the need to specify which actors authorize, review, maintain, and correct which components of the process. The responsibility-retention logic developed earlier in the chapter is therefore central to public-sector deployment.

Institutional learning adds the temporal dimension. Public agencies can improve when they accumulate case knowledge, detect recurring failures, revise procedures, train personnel, and preserve records that make later review possible. Heavy de-

pendence on external technical systems can either support or weaken these capacities. A system that captures high-quality records and makes patterns inspectable can strengthen learning; one that produces decisions without durable institutional understanding can create operational success alongside capability erosion. Section 18.16 therefore directs attention to whether public institutions remain able to revise the technical and procedural arrangements they use.

Public participation also extends beyond individual appeal. AI can help analyze consultations, translate materials, simulate policy effects, or widen access to public information. These capacities can increase participation if they enable persons and collective subjects to shape problem formation and policy alternatives. They can produce a thinner participatory form if citizens are invited to react only after problem framing and option generation have been effectively settled. The generative-participation distinction of Section 18.14 thus applies directly to democratic and administrative design without assuming one constitutional model.

Proposition 18.279 (Revisable public-authority condition). *An AI-mediated public institution is more governable when technical capacity remains embedded in identifiable public mandates, contestable procedures, preserved institutional knowledge, traceable responsibility, maintainable operational alternatives, and review mechanisms through which changed evidence or conditions can support revision.*

The proposition permits extensive automation and decision support where domain evidence and law support them. Its purpose is to preserve the institutional relation through which technical action becomes public action and through which errors, changed conditions, and contested values can re-enter governance.

18.17.8 Domain Interface Synthesis

The seven interfaces show why the general architecture of AI asymmetry requires domain translation before it can guide substantive inquiry. Education makes capability formation and judgment especially salient. Research foregrounds epistemic regeneration and orientation. Work foregrounds livelihood, organizational participation, developmental pathways, and surplus recirculation. Development foregrounds conversion of access into locally reproducible capability and the terms of dependency. Communities foreground relational capacity, representation, and governance of shared resources. Ecology foregrounds represented affectedness, irreversibility, regeneration, and heterogeneous value. Public institutions foreground authority, contestability, responsibility, and institutional learning. These emphases overlap, but their relative importance and evidential forms differ.

The common analytical sequence is therefore one of disciplined translation. A domain inquiry first identifies the relevant subjects and relations; it then specifies the artificial capabilities and infrastructures entering those relations; it examines how capability differences convert into dependence, access, or power; it identifies the values and forms of standing implicated; it traces allocation, surplus, and participation effects where relevant; and it extends the analysis through time to determine which capabilities, institutions, knowledge practices, and alternatives are reproduced. Each step can be revised when domain evidence indicates that the general categories are incomplete or differently organized.

Definition 18.280 (Domain-translation remainder). *A domain-translation remainder is a domain-relevant object, relation, value, mechanism, history, or constraint whose analytical significance is not adequately represented by the chapter-level categories carried into the domain and therefore requires domain-specific conceptualization or revision of the general framework.*

The remainder is methodologically important because GRE is intended as an open research programme. A framework becomes less useful when every domain is forced to confirm its existing vocabulary. Domain inquiry should therefore be capable of modifying the framework. Education may require concepts of learning or development that exceed generic capability categories. Ecology may require representations of interdependence or regeneration that change the economic vocabulary. Public institutions may impose legal categories requiring independent specification beyond general relational analysis. Research may reveal epistemic institutions whose functions alter the prior account of knowledge capital. Such findings feed back into GRE as framework revisions.

Comparison across domains should therefore preserve both recurrence and difference. Dependency, power conversion, participation, value mediation, and long-horizon openness may recur across several interfaces, allowing comparative analysis of mechanisms. Their operational meaning can nevertheless differ. Dependence on an AI tutor, a laboratory model service, a workplace platform, a development infrastructure, or a public administrative system involves different exit costs, rights, stakes, and institutional remedies. Cross-domain analogy is informative when these differences remain explicit.

The chapter's treatment of radical capability asymmetry can now be stated in integrated form. Artificial productive capacity matters economically through the relations that make it accessible and consequential. Capability asymmetry becomes power only through specified mechanisms of dependency, control, or mediation. Labor effects depend on task composition, organizational arrangements, bargaining relations, and the reproduction of expertise. Ownership and infrastructure shape the capture and circulation of AI-generated surplus. Redistribution can secure important material conditions while leaving access, participation, institutional standing, and capability formation unresolved. Human–AI relations can produce complementarity, delegation, dependence, substitution, and co-generation in different configurations. Epistemic abundance relocates scarcity toward verification, provenance, attention, and judgment. Governance therefore concerns contestability, reversibility, responsibility, dependency reduction, infrastructure, and preservation of human action space. Generative participation asks whether subjects remain able to shape later knowledge, institutions, communities, and alternatives. Heterogeneous subject–value configurations prevent operational similarity from silently becoming equivalence of standing or value. Long-horizon analysis finally asks whether the resulting order reproduces capacities for revision and alternative formation.

Proposition 18.281 (Domain-transfer condition). *A Chapter 18 concept has stronger analytical warrant in a substantive domain when its relevant subjects, relations, mechanisms, value dimensions, temporal scale, and evidential indicators can be specified within that domain, while material domain-translation remainders remain available to revise or limit the transferred concept.*

Proposition 18.281 closes the chapter by defining the relation between its general AI architecture and the domain inquiries that follow. The next chapter therefore begins with domain translation before developing education, research and knowledge institutions, work and organizations, development and humanitarian practice, welfare and social protection, communities and commons, platforms and digital economies, public institutions and infrastructure, migration and transnational relations, ecology, and culture and symbolic economy. Those inquiries can use the present chapter's distinctions as starting coordinates while testing their adequacy against domain-specific evidence and concepts.

Chapter 18 has treated artificial intelligence within historically developing economic configurations, with its capabilities becoming consequential through relational embedding. The chapter's central concern has been the conversion of artificial capability into relational consequences: power, dependence, allocation, surplus, participation, epistemic structure, institutional authority, and future possibility. The domain interfaces developed in the present section provide the boundary condition for carrying that analysis forward. They preserve the general architecture where it illuminates the domain, expose remainders where it does not, and keep later domain inquiry capable of revising the framework from which it begins.

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