

Knowledge-Capital Expansion in the Public Knowledge Commons: A Foundational Inquiry

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Abstract

This paper develops a foundational inquiry into knowledge-capital expansion under conditions of public knowledge. Its starting point is the observation that epistemic resources may influence more than the immediate production of knowledge. Accumulated propositions, questions, concepts, methods, data, technical capacities, and other epistemic resources can alter an actor's subsequent capacity to generate further knowledge. Knowledge may therefore acquire capital-like properties when previous epistemic production becomes a productive condition of later epistemic production. The paper introduces knowledge capital, knowledge-capital expansion, epistemic capitalization, capitalization capacity, capitalization asymmetry, and recursive epistemic advantage as preliminary concepts for examining this process.

The inquiry places these concepts in dialogue with several intellectual traditions, including classical and Marxian political economy, theories of capital and accumulation, Kantian epistemology and the conditions of knowledge, human and intellectual capital, forms and conversion of capital, the sociology of science, knowledge-commons scholarship, academic and platform capitalism, epistemic injustice, and generative justice. Particular attention is given to the distinction between the dynamics of capital-like expansion and positions within relations of production. Knowledge-capital expansion concerns a dynamical structure through which epistemic resources recursively enlarge future generative capacities. A knowledge capitalist, by contrast, denotes a relational position characterized by control over significant means and conditions of epistemic production. Rapid epistemic accumulation consequently does not by itself determine an actor's position within capitalist relations.

Public knowledge creates a further theoretical problem. Shared epistemic resources can enlarge collective possibilities of inquiry while producing unequal gains among actors with different prior knowledge, time, infrastructure, institutional access, networks, computational resources, and other capitalization conditions. The paper develops this problem through the concepts of public knowledge as generative infrastructure, capitalization asymmetry, cross-domain recombination, cross-capital conversion, and an openness–concentration paradox. Questions themselves are also examined as potential epistemic resources when they enlarge the space of possible future inquiry.

Artificial intelligence is considered as a contemporary amplifier of these dynamics because machine-scaled epistemic infrastructure can increase the volume and range of publicly accessible knowledge that becomes practically capitalizable. The paper treats this development as one case within the wider theory and leaves its fuller political economy to subsequent research. The discussion also identifies preliminary ethical and jurisprudential implications concerning appropriation, generative extraction, recirculation, ownership, stewardship, and enclosure. These issues remain open research directions. The resulting framework is offered as a provisional basis for investigating the dynamics, relational structures, institutional conditions, and unresolved normative questions surrounding knowledge-capital expansion in the public knowledge commons.

Keywords: knowledge capital; knowledge-capital expansion; public knowledge commons; epistemic capitalization; capitalization asymmetry; political economy; epistemic generativity; recursive accumulation; knowledge production; artificial intelligence

Discussion Paper Note

This paper is a foundational conceptual inquiry into knowledge-capital expansion under conditions of public knowledge. Its purpose is not to establish a complete theory of knowledge, capital, knowledge production, or the knowledge commons. It instead develops a preliminary conceptual vocabulary for examining a recurring phenomenon: epistemic resources generated or acquired at one stage of inquiry may alter the conditions under which subsequent inquiry becomes possible, thereby contributing to further epistemic generation.

The paper begins from the observation that knowledge accumulation need not be purely additive. If K_t denotes epistemic resources available at time t , and G_t denotes a subject's or system's capacity for subsequent epistemic generation, a minimal recursive structure may be written as

$$K_t \longrightarrow G_{t+1} \longrightarrow K_{t+1}. \quad (1)$$

Equation 1 does not claim that knowledge production follows a universal deterministic law. Nor does it imply that every increase in knowledge necessarily increases future generative capacity. Epistemic resources may become obsolete, misleading, inaccessible, incommensurable, institutionally unusable, or generatively unproductive. The relation is introduced as an analytical possibility whose conditions, limits, and empirical manifestations require further investigation.

The term *knowledge capital* is therefore used cautiously. The paper does not assume that knowledge is capital merely because it is valuable, scarce, productive, accumulable, or economically consequential. The capital analogy becomes analytically relevant where an epistemic resource can enter a recursive process in which previous epistemic acquisition modifies the capacity for subsequent epistemic production.

For this purpose, the paper adopts a deliberately broad provisional category of epistemic resources,

$$K = \{P, Q, C, M, D, T, \dots\}, \quad (2)$$

where P may include propositions or established knowledge, Q questions, C concepts and distinctions, M methods, D data or archives, and T tools, techniques, or other epistemically consequential resources. The list is neither exhaustive nor ontologically homogeneous. Its purpose is to prevent knowledge capital from being reduced prematurely to a stock of codified propositions.

Questions are especially important in this respect. An epistemically productive question may enlarge the space of possible subsequent inquiry without itself constituting an answer. A schematic process can therefore take the form

$$K_t \longrightarrow Q_{t+1} \longrightarrow \Omega_{t+1} \longrightarrow K_{t+1}, \quad (3)$$

where Ω_{t+1} denotes a changed possibility space of inquiry. Equation 3 is used to emphasize that epistemic production may accumulate conditions for future questioning as well as completed answers.

The vocabulary of capital also requires careful differentiation. The paper does not use *capital*, *capitalization*, *accumulation*, *expansion*, *reproduction*, *concentration*, and *centralization* as interchangeable expressions. Classical political economy, Marxian political economy, later Marxist traditions, and contemporary economic theories employ these concepts within different theoretical architectures. Their historical and conceptual relations are therefore reviewed before the paper introduces knowledge-capital expansion as its own analytical category.

Marxian political economy is particularly important because it distinguishes the movement and reproduction of capital from the social positions occupied within capitalist relations of production. The present inquiry develops an analogous analytical distinction without presupposing identity between industrial capital and epistemic production.

The distinction may be stated schematically as

$$\text{knowledge-capital expansion} \not\Rightarrow \text{knowledge-capitalist position}. \quad (4)$$

Knowledge-capital expansion concerns a dynamical structure. It asks how epistemic resources accumulate, recombine, reproduce, convert, and alter future generative capacity. A knowledge capitalist, by contrast, denotes a position within a relational structure of epistemic production. The relevant questions concern control over means and conditions of knowledge production, the organization of epistemic labor, appropriation, dependency, access, recognition, and the capacity to govern future generative conditions.

The distinction can be summarized through two analytical objects:

$$\mathcal{D}_K = \text{dynamics of knowledge-capital expansion}, \quad \mathcal{R}_E = \text{relations of epistemic production}. \quad (5)$$

No one-to-one correspondence between $\mathcal{D}_K$ and $\mathcal{R}_E$ is assumed. A subject may exhibit rapid recursive knowledge-capital expansion while occupying no capitalist position in the relevant relations of production. Conversely, an actor may control substantial means of epistemic production while possessing comparatively little of the embodied knowledge involved in the resulting epistemic output.

This separation is necessary because accumulation alone does not determine the political character of accumulation. Epistemic resources may enter proprietary cycles, commons-oriented cycles, institutional cycles, cooperative cycles, or other forms of circulation. The paper therefore distinguishes accumulation from enclosure and leaves open the possibility that substantial accumulation may coexist with extensive public recirculation.

The public knowledge commons introduces a second major problem. Public availability does not imply equal capacity for productive use. Actors differ in prior knowledge, language, time, institutional access, education, networks, funding, computational infrastructure, publication channels, and other generative conditions. Formally similar access to the same epistemic resource may therefore yield heterogeneous changes in subsequent generative capacity:

$$\Delta G_A(C) \neq \Delta G_B(C), \quad (6)$$

where C denotes an accessible epistemic resource or commons condition.

Equation 6 does not imply that inequality is produced by openness itself. The paper instead examines the possibility that openness can interact with pre-existing differences in capitalization capacity. A knowledge commons may consequently increase aggregate epistemic generativity while also permitting unequal recursive gains.

The resulting tension is provisionally described as an *openness–concentration paradox*. The expression does not assert that greater openness necessarily causes greater concentration. It identifies a research problem concerning conditions under which wider access and increasing concentration of effective epistemic capacity may coexist.

The paper also distinguishes access, possession, ownership, control, and appropriation. These categories become especially important because knowledge is frequently non-rival or partially non-rival. One actor's possession of an epistemic resource does not necessarily deprive another actor of possession of the same resource. The politically significant transformation may therefore occur when shared epistemic resources are converted into control over future generative conditions.

A simplified commons-to-private capitalization trajectory may be represented as

$$K_{\text{public}} \longrightarrow G'_A \longrightarrow K'_A \longrightarrow C'_A, \quad (7)$$

where C'_A represents an enlarged set of generative conditions available to actor A . The trajectory is not inherently exploitative. Its normative status depends upon additional relations, including the origin of the resources, conditions of access, modes of appropriation, effects on other actors, enclosure, dependency, recirculation, and regeneration of the source field.

The paper therefore uses *generative extraction* and *generative exploitation* cautiously. Unequal capitalization is not automatically extraction, and extraction is not automatically exploitation. The stronger normative vocabulary requires further criteria concerning appropriation, degradation, suppression, dependency, or loss of future generativity. These criteria are introduced as open problems rather than settled conclusions.

Knowledge capital may also interact with other forms of capital. Epistemic resources can contribute to reputation, institutional position, financial resources, networks, infrastructure, and visibility, which may subsequently alter the conditions of further epistemic production. A provisional cross-capital representation is

$$\mathbf{C} = (K, R, F, N, S, I, \dots), \quad (8)$$

where K denotes epistemic capital, R reputational resources, F financial resources, N network resources, S status or institutional resources, and I infrastructural resources.

A recursive conversion trajectory may then take the form

$$K \longrightarrow R, F, N, S, I \longrightarrow G' \longrightarrow K'. \quad (9)$$

Equation 9 is a conceptual scaffold rather than a universal causal sequence. Different institutions and historical contexts may permit, restrict, reverse, or interrupt particular conversions.

Kantian epistemology enters the inquiry through a different theoretical problem. The paper is concerned not only with quantities of information but with conditions under which epistemic objects become available to a knowing subject. Kantian questions concerning the conditions of possible knowledge therefore provide an important philosophical interlocutor for distinguishing an epistemic resource from the conditions that permit that resource to become generatively operative.

The present paper does not attempt to reconstruct Kantian epistemology into a theory of capital. Nor does it claim that Kant's transcendental conditions are equivalent to the material, relational, institutional, or technological generative conditions examined here. The comparison instead helps clarify a more general problem: access to an object or representation does not by itself specify the conditions through which that object becomes knowable, usable, or generative for a particular epistemic subject.

This concern also limits the scope of capitalization. Codified, embodied, relational, situated, and temporally formed knowledge may differ substantially in their transferability and capitalization dynamics. The present foundational paper identifies this problem but does not attempt a complete epistemology of embodied or relational knowing.

Artificial intelligence is treated as a historically important amplifier rather than the defining origin of knowledge-capital expansion. AI systems can alter epistemic absorption capacity, search scale, recombination, question generation, drafting, filtering, and other stages of knowledge production. They may therefore reduce the gap between publicly accessible knowledge and knowledge that an actor can practically capitalize upon.

The paper nevertheless avoids inferring that AI-mediated production is equivalent to human knowing. It also avoids treating every use of AI as capital-intensive or capitalist. The relevant questions concern the ownership, control, accessibility, scale, infrastructure, labor relations, and recursive effects through which AI becomes embedded in epistemic production.

A particularly important possibility is a shift from enclosure of completed knowledge products toward control over knowledge-generating capacity:

$$K_{\text{public}} \longrightarrow I_{\text{private}} \longrightarrow G'_{\text{private}}, \quad (10)$$

where I_{private} denotes privately controlled epistemic infrastructure and G'_{private} denotes an enlarged capacity for future generation. The paper introduces this possibility only as a bounded contemporary extension. A fuller political economy of industrialized epistemic capitalization is reserved for subsequent work.

Ethical and jurisprudential questions are likewise treated as implications of the foundational analysis rather than as problems resolved within the present paper. The discussion considers issues including accumulation, appropriation, generative extraction, recirculation, responsibilities toward commons, priority, provenance, proprietorship, stewardship, ownership, and enclosure. The paper does not derive a general moral duty to return all epistemic value to the commons, nor does it assume that public knowledge requires the elimination of identifiable legal ownership.

The jurisprudential problem is therefore left open: legal subjectivity may serve attribution, provenance, integrity, accountability, or remedy while also creating possibilities for exclusion and control. Whether a form of retained or stewardship-oriented rights can protect public epistemic circulation without reconstructing conceptual monopoly requires dedicated legal analysis across specific jurisdictions and rights regimes.

Similarly, the paper does not claim that one existing open license already solves the problems identified here. Copyright, moral rights, attribution, contract, database rights, public-domain status, model training, derivative production, integrity, and remedies operate through different legal architectures. Their interaction requires separate and jurisdiction-sensitive research.

The analytical framework is consequently descriptive, explanatory, and problem-generating before it is normative. It seeks to distinguish processes that are often conflated and to identify conditions under which different epistemic trajectories may emerge. Its concepts remain provisional and revisable.

The orientation of the paper can be summarized through five methodological commitments:

Knowledge capital is examined through its generative consequences rather than treated as a synonym for information or knowledge stock. Capital-like expansion is examined as a dynamical structure rather than identified with capitalist social position. Public access is distinguished from effective capitalization capacity. Accumulation is distinguished from appropriation and enclosure. Normative and jurisprudential consequences are identified without being prematurely settled within the foundational inquiry.

The Introduction develops the motivating phenomenon and scope of the inquiry. The Literature Review reconstructs relevant traditions in political economy, Marxian theories of capital and accumulation, Kantian epistemology, theories of knowledge and intellectual capital, sociology of science, knowledge commons, generative justice, and contemporary political economies of knowledge. The subsequent sections develop the conceptual vocabulary, expansion dynamics, public-commons conditions, relational positions of epistemic production, a preliminary analytical framework, and the contemporary amplification associated with artificial intelligence. The Discussion considers broader theoretical, ethical, and jurisprudential implications, while the final open-problems section preserves unresolved conceptual, empirical, normative, jurisprudential, epistemological, and methodological questions for the wider research programme.

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Statement on the use of language models. The exploratory discussions and preparation of this paper involved OpenAI’s ChatGPT. ChatGPT supported exploratory dialogue, formal reconstruction, source discovery followed by website verification, exact calculation, argumentative criticism, and drafting in $\text{\LaTeX}$. The author selected the research questions, directed and approved the theoretical commitments and epistemic status of the claims, and bears sole responsibility for the manuscript, including its definitions, formal constructions, taxonomy, calculations, arguments, conclusions, and errors. Authorship credit remains with the human author. The access level and claim limit for every cited source are recorded in the accompanying literature audit.

1 Introduction

This section establishes the research object, conceptual motivation, analytical scope, and programme of the present inquiry. The discussion begins from the recursive relation between accumulated epistemic resources and subsequent knowledge-generating capacity, then situates this relation within the political economy of capital, the epistemology of knowledge conditions, the sociology of cumulative advantage, and scholarship on knowledge commons. The section next introduces the distinction between knowledge-capital expansion as a dynamical structure and the knowledge capitalist as a position within relations of epistemic production. It then develops the problem created by public knowledge: shared epistemic resources can support broad knowledge generation while actors retain markedly heterogeneous capacities to capitalize upon those resources. The final part defines the scope of the foundational inquiry and locates its later extensions into artificial intelligence, ethics, jurisprudence, epistemology, and epistemic praxis.

Knowledge is commonly described through metaphors of accumulation. Individuals acquire knowledge, disciplines accumulate findings, archives preserve previous work, and scientific communities enlarge bodies of theory, data, methods, and technical capability. Such descriptions can suggest an additive structure in which later knowledge is appended to an expanding stock. Epistemic development, however, can also transform the conditions of subsequent generation. A concept learned at one stage can enable recognition of previously unavailable questions. A mathematical method can make a new class of problems tractable. Knowledge of two previously separate fields can support combinations that were unavailable within either field alone. A database, archive, instrument, computational tool, language, or theoretical distinction can alter the range, rate, direction, and practical feasibility of subsequent inquiry. Accumulated epistemic resources can therefore participate in the production of further epistemic resources.

The resulting process has a recursive character. If K_t denotes the epistemic resources available to an actor or system at time t , and G_t denotes the capacity through which further epistemic resources can be generated, the relation of interest can be represented compactly as $K_t \rightarrow G_{t+1} \rightarrow K_{t+1}$. The analytical significance lies in the intermediate transformation of generative capacity. Previous knowledge can contribute to the production of later knowledge through the changes it produces in the conditions of inquiry itself. The present paper uses the expression *knowledge-capital expansion* for this broader family of recursive processes and develops *epistemic capitalization* for the conversion of accessible epistemic resources into enhanced conditions of subsequent epistemic generation.

The vocabulary of capital requires careful conceptual treatment. Political economy contains several distinct traditions concerning capital, accumulation, reproduction, ownership, labor, and productive conditions. Marx's analysis gives particular importance to the movement of capital through processes of valorization and accumulation and treats capital through a social organization of production rather than through a purely static collection of productive things [13]. The Marxian framework also connects accumulation with relations among owners of capital, workers, means of production, and processes through which surplus becomes incorporated into further production. These distinctions provide an important conceptual interlocutor for knowledge production because they separate the dynamics through which capital expands from the positions occupied by actors within the relations that organize production.

The present inquiry carries that separation into the epistemic domain. *Knowledge-capital expansion* designates a dynamical structure involving generation, accumulation, capitalization, recombination, conversion, and recursive change in future productive capacity. The expression *knowledge capitalist* designates a relational position associated with substantial control over means and conditions of epistemic production. The first concept concerns trajectories and feedback processes. The second concerns relations among actors, infrastructures, productive conditions, epistemic labor, access, control, and appropriation. These analytical dimensions can vary independently. A researcher can undergo rapid knowledge-capital expansion while maintaining extensive circulation of outputs and limited control over other producers. An institution or infrastructure owner can occupy a powerful position within epistemic production while possessing only a fraction of the embodied knowledge involved in the resulting outputs.

This distinction provides one of the principal organizing commitments of the paper:

Capital-like expansion is a dynamic property; capitalist position is a relational property.

The distinction also permits a more precise engagement with accumulation. Accumulation can occur across heterogeneous relational arrangements. Epistemic resources can accumulate within individual learning, collaborative research, public archives, universities, firms, open-source communities, scientific networks, state institutions, and other organizational forms. The political character of an accumulation process consequently depends upon additional relations concerning control, access, labor, appropriation, circulation, dependency, and the reproduction of generative conditions. The analytical separation between expansion and relational position therefore precedes the later normative evaluation of particular forms of knowledge-capital accumulation.

The concept of knowledge capital also intersects with a different philosophical lineage concerning the conditions of knowledge. Kant's critical philosophy places the conditions and limits of cognition at the center of epistemological inquiry and examines the contributions of sensibility, understanding, and reason to human knowledge [10]. The present paper operates at a different analytical level, yet the Kantian orientation toward conditions of possibility remains relevant. An epistemic resource can become productive only through conditions that allow an actor to recognize, interpret, combine, apply, or transform it. Formal availability of information therefore supplies only one component of epistemic generation. Previous knowledge, conceptual schemes, language, training, material resources, time, institutional access, instruments, computational infrastructure, social relations, and other conditions can influence whether an available resource becomes generatively operative.

This conditional structure becomes especially significant under public knowledge. Scholarship on knowledge commons has developed an extensive account of knowledge as a shared resource and has examined access, governance, intellectual property, open scholarly communication, collaborative production, and possible enclosure in digital environments [9]. Public availability can enlarge the range of resources from which subsequent inquiry proceeds. A theorem, dataset, archive, article, software library, conceptual distinction, or research question placed into public circulation can enter productive processes far beyond the institution or person from which it originated.

Public availability nevertheless interacts with heterogeneous productive conditions. Two actors can encounter the same accessible epistemic resource while possessing different prior knowledge, education, languages, time, funding, institutional affiliation, networks, computational resources, publication access, and technical infrastructure. The same epistemic input can therefore produce different changes in their subsequent generative capacities. The present paper describes this relation through *capitalization capacity* and *capitalization asymmetry*. Equal formal access to a resource can coexist with unequal capacity to incorporate that resource into further cycles of knowledge generation.

The sociology of science supplies an important neighboring account of recursive inequality. Merton's analysis of cumulative advantage examines processes through which differences in scientific recognition, resources, opportunities, and subsequent rewards can accumulate over time [14]. Knowledge-capital expansion shares an interest in self-reinforcing trajectories while extending the analytical object toward the generative consequences of epistemic resources themselves. A previous advantage can consist in reputation or institutional opportunity, and it can also consist in possessing a conceptual, methodological, linguistic, computational, or relational resource that changes the capacity to capitalize on the next accessible resource. The relevant recursion therefore involves both the social distribution of opportunity and the transformation of epistemic productive capacity.

Such recursion can extend across different forms of capital. Epistemic production can generate reputation, credentials, institutional position, funding, networks, visibility, infrastructure, and access to further collaboration. These resources can subsequently alter the conditions of later epistemic production. Knowledge capital therefore participates in potential conversion cycles linking epistemic, reputational, financial, network, institutional, and infrastructural resources. Research on academic capitalism has already examined organizational arrangements through which universities and academic actors become increasingly connected to markets, commercialization, intellectual property, and revenue-generating circuits [18]. The present inquiry extends the problem toward recursive generative capacity: accumulated

epistemic resources and their converted returns can alter an actor's ability to acquire, recombine, produce, circulate, and capitalize upon further knowledge.

Questions themselves expand the scope of the inquiry beyond conventional representations of knowledge as a stock of established propositions. A question can have generative consequences before an answer exists. A new question can identify previously unrecognized variables, establish a new comparison, reveal a missing dataset, motivate a method, connect separate literatures, reorganize an existing problem, or generate further questions. Epistemic accumulation can therefore include expansion of the space of possible inquiry. Concepts, distinctions, methods, questions, data, tools, archives, and trained interpretive capacities can all become candidates for knowledge capital when their presence changes the possibilities of subsequent generation.

Cross-domain knowledge further introduces combinatorial effects. An epistemic resource acquired in one field can enter another field as a conceptual, formal, methodological, or heuristic resource. The resulting combination can then modify the original field or create an intermediate research space. The productive significance of interdisciplinary accumulation therefore depends partly on relations among resources. An expanding knowledge system acquires new nodes and new possible connections among existing nodes. This relational dimension helps explain why equivalent increments in informational quantity can produce markedly different changes in generative capacity.

The public knowledge commons consequently presents a structural tension. Broader circulation can increase the generative resources available throughout a field while heterogeneous capitalization capacities produce unequal gains from those resources. Under some conditions, actors already possessing strong epistemic, financial, institutional, network, or infrastructural resources can convert public knowledge into further private or organizational advantage at a higher rate. The enlarged advantage can subsequently increase their capacity to capitalize upon the next round of public resources. The paper uses *openness–concentration paradox* as a provisional name for situations in which expansion of shared epistemic accessibility coexists with increasing concentration of effective knowledge-generating capacity. The expression identifies a theoretical possibility whose causal conditions, empirical frequency, and institutional variation remain open to investigation.

Questions of circulation and extraction follow from the same structure. Generative justice provides a relevant conceptual resource through its emphasis on the circulation of value and the relation between generated value and the people or systems from which that value emerges [5]. Applied to knowledge commons, this perspective directs attention toward the trajectory followed by publicly available epistemic value after capitalization. Some trajectories can contribute to further public generativity through open methods, concepts, data, teaching, infrastructure, or other forms of recirculation. Other trajectories can increase exclusive control over subsequent generative conditions. These possibilities motivate later distinctions among accumulation, appropriation, generative extraction, enclosure, and generative return.

Artificial intelligence gives these questions renewed practical significance. AI systems are increasingly used across multiple stages of scientific work, and policy discussions have emphasized their potential effects on research productivity, discovery, scientific infrastructure, and research governance [15]. AI can expand the volume of information that an actor can search, summarize, compare, translate, classify, and recombine within a given period. Agentic and computational infrastructures can also support parallel exploration of candidate questions, hypotheses, methods, and textual outputs. These capabilities can enlarge the set of publicly accessible epistemic resources that becomes practically capitalizable for actors who possess the required infrastructure and complementary capacities.

The present foundational inquiry treats AI as a contemporary amplification of a more general mechanism. Knowledge-capital expansion precedes current generative AI and can occur through human learning, libraries, institutions, collaboration, disciplinary specialization, computational tools, and other historical means of epistemic production. AI changes the potential scale, speed, parallelism, and infrastructural organization of several processes already contained within the broader framework. Its fuller political economy, including machine-scaled production, infrastructural epistemic capital, automated capitalization, and possible concentration of knowledge-generating capacity, therefore constitutes a major extension of the present paper.

The conceptual framework also generates ethical and jurisprudential questions. Rapid knowledge-capital expansion alone supplies insufficient information for evaluating the justice of an epistemic arrangement. Normative assessment requires attention to the relations through which generative resources were obtained, the distribution of productive conditions, the organization and recognition of epistemic labor, the degree of dependency created, the circulation of resulting value, and the effects of accumulation on other actors' future generativity. Similar distinctions matter in jurisprudence. Ownership, possession, access, control, appropriation, attribution, provenance, and stewardship represent different legal or practical relations to epistemic resources. Public circulation can therefore coexist with identifiable rights holders, while particular configurations of rights can also facilitate enclosure or control over future generative conditions.

These normative and jurisprudential implications enter the Discussion as research frontiers generated by the foundational analysis. Detailed ethical criteria for generative extraction and exploitation belong to a subsequent normative inquiry. Detailed legal analysis of retained rights, licensing, attribution, integrity, stewardship, public-domain status, and remedies requires jurisdiction-sensitive jurisprudential research. The present paper supplies conceptual distinctions through which those later questions can be formulated with greater precision.

The inquiry therefore pursues several connected objectives. It develops a provisional concept of knowledge capital grounded in generative consequence; distinguishes knowledge-capital expansion from adjacent concepts of knowledge stock and informational accumulation; develops epistemic capitalization, capitalization capacity, capitalization asymmetry, and recursive epistemic advantage; examines questions and cross-domain relations as components of epistemic generativity; analyzes public knowledge as shared generative infrastructure; distinguishes expansion dynamics from positions within relations of epistemic production; introduces the categories of knowledge capitalist and epistemic proletariat for later development; examines cross-capital conversion and possible openness–concentration dynamics; and uses contemporary AI as a bounded case through which the scale implications of the framework become visible.

The resulting framework remains deliberately foundational. Its concepts are provisional analytical instruments whose boundaries require historical, philosophical, institutional, and empirical testing. The paper therefore retains open questions concerning the boundary of capital terminology, relations among valorization, accumulation, reproduction, expansion, concentration, and centralization, the measurement of epistemic generativity, the empirical identification of capitalization asymmetry, the aggregation of knowledge capital across individual and institutional levels, the limits of capitalization for embodied and relational knowledge, and the normative thresholds separating productive use, appropriation, extraction, and exploitation.

The paper proceeds from this introduction to a broad Literature Review. The review reconstructs relevant concepts from classical and Marxian political economy, Kantian epistemology, theories of human and intellectual capital, capital conversion, sociology of science, knowledge-commons scholarship, academic and platform capitalism, epistemic injustice, generative justice, and the emerging political economy of AI. The conceptual sections then define knowledge capital and its principal categories before examining the dynamics of recursive expansion and the distinctive conditions created by public knowledge. A subsequent political-economic analysis develops means of epistemic production, control over generative conditions, knowledge capitalists, epistemic proletariat, dependency, subordination, appropriation, and extraction. The preliminary analytical framework organizes these relations across actors, epistemic resources, generative conditions, and cross-capital feedback. The AI section examines contemporary amplification without exhausting the dedicated AI-specific research programme. The Discussion develops theoretical, ethical, and jurisprudential implications. The final open-problems section preserves the conceptual, empirical, normative, legal, epistemological, and methodological questions that remain available for subsequent research.

2 Literature Review

This section establishes the intellectual context required for a foundational account of knowledge-capital expansion. The review has four objectives. First, it reconstructs distinctions among capital, accumulation, expansion, reproduction, productive conditions, and capitalist position in classical and Marxian political economy. Second, it examines philosophical and economic traditions concerned with the conditions, production, and productive use of knowledge. Third, it reviews literatures concerned with unequal accumulation, commons governance, institutional and infrastructural power, epistemic participation, and value circulation. Fourth, it locates contemporary artificial intelligence within these longer histories of epistemic production. The section uses conceptual comparison across these literatures to identify their respective analytical objects and to delimit the theoretical space occupied by the present inquiry.

2.1 Capital and Accumulation in Classical Political Economy

This subsection establishes the pre-Marxian political-economic background of capital and accumulation. The discussion focuses on Adam Smith and David Ricardo because their analyses already distinguish productive resources, accumulation processes, income distributions, and social positions associated with ownership of capital. These distinctions provide an important historical basis for separating the dynamics of capital from the position of a capitalist.

In *An Inquiry into the Nature and Causes of the Wealth of Nations*, Smith organizes Book II around the nature, accumulation, and employment of stock [19]. A central distinction separates the portion of a person's stock reserved for immediate consumption from the portion employed with an expectation of revenue. Capital thereby receives a productive orientation: accumulated stock can support productive activity and the further division of labor. Accumulation consequently has consequences beyond the quantity of wealth already possessed. It changes the productive resources available for subsequent economic activity.

This feature is relevant to the present inquiry because a resource acquires a capital-like character partly through its relation to subsequent production. The analogy nevertheless requires domain-specific reconstruction. Smith's capital concerns economic stock employed for revenue-generating activity, whereas the present inquiry examines epistemic resources whose accumulation changes future capacities for knowledge generation. The conceptual connection lies in the relation between previously accumulated resources and subsequent productive possibilities.

Ricardo places distribution among the central problems of political economy. The preface to *On the Principles of Political Economy and Taxation* identifies landlords, owners of capital, and laborers as distinct classes among whom social production is distributed through rent, profit, and wages [16]. Ricardo also examines accumulation in relation to profits, wages, population, trade, and the employment of capital. His analysis therefore combines a theory of productive resources with a theory of distribution among differently positioned actors.

Smith and Ricardo together provide an early conceptual separation among capital as a productive resource, accumulation as a process through time, and capital ownership as a position relevant to distribution. These categories remain tightly connected within classical political economy while retaining different analytical functions. The distinction becomes substantially more developed in Marxian political economy.

2.2 Marxian Capital and Valorization

This subsection reconstructs the dynamic conception of capital developed in Marx's *Capital*. Its role is to clarify the relation among capital, valorization, circulation, and expansion before the present paper introduces knowledge-capital expansion. Particular attention is given to capital as a process whose continuation depends upon repeated transformation and augmentation.

Marx's analysis of the general formula for capital begins from the circuit in which money is advanced, converted through commodity relations, and returns in an augmented monetary form [13]. The analytical

importance of this circuit lies in the movement of value through successive forms and in the augmentation that gives the circuit its specifically capitalist character. Capital therefore has a temporal and processual dimension. A quantity of value functions as capital through its participation in relations and processes that permit valorization.

This dynamic conception is significant for the present inquiry. A stock-based description records how much of a resource exists at a given moment. A capital-expansion perspective additionally examines how an accumulated resource enters a process that modifies the conditions of subsequent production. The distinction between stock and generative movement provides a conceptual precedent for treating knowledge-capital expansion as a trajectory rather than a static quantity.

Marx's framework also establishes an important constraint on the transfer of capital terminology. Valorization in Marx concerns a historically specific capitalist production process involving commodity production, labor power, surplus value, and relations of production. Epistemic generation has different objects, mechanisms, institutions, and forms of labor. The present inquiry therefore uses the Marxian analysis as a theoretical interlocutor for distinguishing movement, accumulation, productive conditions, and relational positions. The specific categories of Marxian value theory retain their own historical and theoretical domain.

The relevant conceptual inheritance is consequently structural. Capital can be studied through its movement, reproduction, and capacity for augmentation. This permits a parallel question concerning epistemic resources: under which conditions does an epistemic resource enter a recursive process through which previous generation contributes to enlarged conditions for subsequent generation?

2.3 Capitalist Position, Labor, and Means of Production in Marx

This subsection examines the relational dimension of Marxian capital. Its objective is to distinguish the movement of capital from the position occupied by the capitalist within the social organization of production. The discussion also introduces labor power and control over means of production as relational elements that later inform the concepts of knowledge capitalist and epistemic proletariat.

Marx characterizes the capitalist as a bearer or personification of capital within capitalist production [13]. This formulation is especially important for the present framework because the category *capitalist* denotes a position and function within a social relation. The capitalist participates in a structure involving ownership or control of productive resources, acquisition of labor power, organization of production, appropriation of surplus value, and reinvestment into further accumulation.

The capitalist can consequently be distinguished analytically from capital itself. Capital has circuits, rates, compositions, accumulation dynamics, and reproductive processes. The capitalist occupies a position through which particular functions of capital are organized and enacted. Marx's description of the capitalist as personified capital makes their connection especially close while preserving the conceptual distinction between a dynamic process and the social bearer of that process.

The relation to means of production is equally significant. Capitalist production presupposes historically constituted relations in which workers possess labor power while access to principal means of production is organized through property and control structures. The resulting relation shapes who can initiate production, who directs productive activity, who depends upon access controlled by another actor, and how the resulting value enters subsequent cycles.

This relational architecture supplies a crucial precedent for the epistemic domain. A person with extensive knowledge does not acquire the analytical position of a knowledge capitalist through quantity of knowledge alone. The relevant category concerns control over significant means and conditions of epistemic production and the capacity to organize, direct, scale, and appropriate epistemic production. Correspondingly, a knowledge producer may possess substantial generative capacity while depending upon institutions, infrastructures, funding, tools, publication systems, or other conditions controlled elsewhere.

The distinction therefore supports one of the foundational separations of the present inquiry: knowledge-capital expansion concerns dynamics, while knowledge-capitalist position concerns relations of epistemic production.

2.4 Reproduction, Accumulation, Concentration, and Centralization in Marx

This subsection differentiates several Marxian processes that can otherwise be compressed into the broad language of capital expansion. Its objective is to prevent the present concept of knowledge-capital expansion from treating valorization, accumulation, reproduction, concentration, and centralization as interchangeable processes.

Marx defines accumulation through the reconversion of surplus value into capital and examines how accumulation contributes to production on an enlarged scale [13]. Accumulation thereby links the result of a previous productive cycle to the productive conditions of a subsequent cycle. Previous accumulation becomes part of the basis for further accumulation. This recursive structure is directly relevant to the present inquiry, although the mechanisms of epistemic capitalization differ from the conversion of surplus value analyzed by Marx.

Reproduction adds another level of analysis. Capitalist production reproduces material inputs and outputs while also reproducing the social conditions under which the production process continues. Expanded reproduction concerns the continuation of production on an enlarged scale. This distinction is useful for knowledge systems because persistence of an epistemic resource and reproduction of the conditions that permit further epistemic generation are analytically separable phenomena.

Marx further distinguishes concentration from centralization. Concentration develops through accumulation and growth of individual capitals, while centralization concerns the redistribution and combination of capitals already formed [13]. A large capital can consequently emerge through internal accumulation, through centralization, or through combinations of these processes. The distinction is particularly important for later analysis of epistemic concentration. Growth in an actor's knowledge-generating capacity through recursive learning has a different structure from acquisition, merger, platform consolidation, institutional aggregation, or control over previously distributed epistemic infrastructures.

The term *knowledge-capital expansion* in the present paper therefore functions as an umbrella analytical category whose internal mechanisms require further differentiation. Recursive epistemic accumulation, cross-capital conversion, concentration of generative capacity, and centralization of epistemic infrastructure can contribute to expansion through different causal pathways.

2.5 Accumulation in Later Marxist Political Economy

This subsection situates Marxian accumulation within later debates concerning the reproduction, geographical extension, and systemic conditions of capital. Its objective is to show how subsequent Marxist scholarship expanded the scale at which accumulation could be analyzed, from individual capital and social reproduction toward broader institutional and spatial configurations.

Luxemburg's *The Accumulation of Capital* places reproduction and expanded reproduction at the center of an inquiry into the broader social conditions of capital accumulation [11]. Her analysis extends the problem beyond an isolated productive unit and examines accumulation through relations connecting capitalist production with wider economic and historical environments. The specific conclusions of Luxemburg's argument generated extensive controversy, while the scale of the question remains relevant: accumulation depends upon conditions distributed across a broader social field.

Harvey develops another influential extension through the spatial, technological, financial, and crisis dynamics of capitalist accumulation [8]. His account emphasizes movement among forms of capital, temporal and spatial displacement, fixed capital, finance, and the geographical organization of production. The result is a conception of capital whose expansion and crisis dynamics depend upon heterogeneous infrastructures and spatially differentiated conditions.

These later developments are relevant to knowledge-capital expansion because epistemic production is similarly distributed across multiple scales. Individual cognition, laboratories, universities, archives, publishers, digital platforms, funding agencies, computational infrastructures, states, and transnational networks can participate in a single generative trajectory. The productive conditions available at one scale can therefore depend upon accumulation, control, and circulation at another.

The later Marxist literature consequently supports a multi-level approach to knowledge capital. Recursive epistemic expansion can be examined through the trajectory of an individual actor while remaining embedded within institutional, infrastructural, and political-economic fields.

2.6 Kantian Epistemology and Conditions of Cognition

This subsection introduces a philosophical literature whose analytical object differs substantially from political economy. Its role is to foreground the importance of conditions under which cognition becomes possible and thereby prevent knowledge capital from being reduced to quantities of externally available information. Kantian epistemology is used here as a conceptual interlocutor concerning epistemic conditions and limits.

The *Critique of Pure Reason* investigates the conditions and limits of human cognition through the relation among sensibility, understanding, and reason [10]. Kant's transcendental inquiry asks about conditions that make cognition of objects possible for a finite discursive knower. Space and time, forms of intuition, and the categories of the understanding occupy different roles within this architecture.

The present inquiry operates at another theoretical level. Its generative conditions include material, cognitive, linguistic, social, institutional, historical, and technological conditions of epistemic production. Kant's transcendental conditions and the present paper's generative conditions therefore belong to distinct explanatory projects. Their comparison remains useful because both direct attention toward the insufficiency of treating an available object as equivalent to a possible act of knowing.

An article, dataset, mathematical formalism, archive, or model can be publicly accessible while remaining practically unavailable to a particular subject as a generative resource. Language, prior conceptual knowledge, disciplinary training, instruments, computational capability, time, and interpretive competence can mediate the transformation of accessibility into epistemic use. The object of interest consequently shifts from the mere presence of an epistemic resource toward the relation between a resource and the conditions through which it becomes generatively consequential.

Kantian epistemology therefore contributes a philosophical caution to the capitalization framework. Formal access does not exhaust the conditions of knowing. This point later becomes important for capitalization asymmetry and for the distinction between public availability and effective epistemic capacity.

2.7 Knowledge Economy and Economics of Information

This subsection reviews economic traditions that explicitly treat knowledge and information as economically consequential resources. Its role is to connect the political-economic literature on capital with scholarship on knowledge production, information characteristics, innovation, and economic growth.

Machlup's *The Production and Distribution of Knowledge in the United States* provided an early systematic attempt to identify and measure sectors devoted to the production and distribution of knowledge [12]. The study widened the economic object beyond formal scientific research and treated educational, informational, communicative, and related activities as components of a knowledge-producing economy. Machlup's contribution is especially relevant because it establishes knowledge production itself as an economic object susceptible to institutional and quantitative analysis.

Arrow's analysis of inventive activity addresses the distinctive economic properties of information and the institutional problems created by invention [1]. Information can be costly to produce while its use and transmission have properties that differ from conventional rival goods. The resulting tension between production incentives, uncertainty, appropriability, and dissemination became foundational for later economics of innovation and knowledge.

Romer's endogenous growth theory further places ideas and technological change inside the growth process [17]. His model emphasizes the nonrival character of technological knowledge together with partial excludability and intentional investment in research. Knowledge can therefore contribute repeatedly to production without being exhausted through a single use. Such properties are directly relevant to public knowledge commons, because wide circulation can coexist with institutional mechanisms of exclusion, licensing, appropriation, and private return.

These traditions establish several properties important for the present framework: knowledge can be produced through resource-intensive processes, knowledge can enter subsequent production, knowledge can generate spillovers, and informational resources frequently display nonrival characteristics. The present inquiry adds a different analytical emphasis by examining changes in the recipient's future capacity to generate further epistemic resources.

2.8 Human Capital and Investment in Productive Capacity

This subsection examines human-capital theory as one of the closest established uses of capital terminology for capacities embodied in persons. Its objective is to distinguish investment in economically productive human capacities from the broader recursive epistemic processes proposed in this paper.

Becker's *Human Capital* develops an economic treatment of investments in education, training, and other activities that alter individual productive capacity and future economic returns [2]. Education can therefore be analyzed as an investment whose costs are incurred in relation to future productivity and earnings.

Human-capital theory provides an important precedent for moving the concept of capital beyond physical assets. Productive capacities embodied in persons can have durable consequences and can be enlarged through investment. The theory also gives time a central role because acquisition of education or training changes later productive possibilities.

Knowledge-capital expansion has a broader analytical object. Epistemic resources can be embodied in persons, encoded in texts, instantiated in infrastructure, embedded in relational systems, distributed across institutions, or publicly available in commons. Questions, conceptual distinctions, methods, archives, software, and networks can become generatively consequential even when their effects cannot be represented adequately through future earnings.

The distinction is therefore one of analytical scope and mechanism. Human capital helps explain investment in productive human capacity. Knowledge-capital expansion examines recursive changes in epistemic generativity across multiple kinds of resources and multiple levels of organization.

2.9 R&D-Based Knowledge Capital

This subsection reviews the econometric tradition that already employs the expression *knowledge capital*. Its role is especially important for terminological clarity because the present inquiry uses the same expression with a substantially broader conceptual definition.

Griliches develops a production-function approach in which accumulated research and development expenditure is represented through an R&D capital stock and related to productivity [7]. This tradition became a major framework for estimating returns to research, technological spillovers, and the contribution of R&D to productivity. Subsequent productivity research frequently refers to such accumulated R&D stocks as knowledge capital.

The R&D-based knowledge-capital model provides an operationally disciplined and empirically useful concept. Its object is usually constructed from research investment, depreciation assumptions, and productivity relationships. The present inquiry addresses a different level of abstraction. It includes epistemic resources whose generative significance may arise through conceptual recombination, question generation, methods, data, trained judgment, networks, or public knowledge, including resources whose formation cannot be represented through R&D expenditure.

This difference also affects the meaning of accumulation. An R&D stock can increase quantitatively while its epistemic components vary in their combinatorial relevance, accessibility, interpretability, or future generativity. Conversely, a single conceptual distinction or research question can produce a large change in future inquiry possibilities with limited correspondence to expenditure-based capital measures.

The present paper therefore retains *knowledge capital* as a broad conceptual category while explicitly recognizing the established econometric use of the term. Later empirical work will require operational definitions suited to specific kinds of epistemic capital.

2.10 Intellectual Capital in Organizational Research

This subsection examines intellectual-capital research at the organizational level. Its objective is to distinguish the present framework from approaches that classify intangible resources according to their contribution to organizational performance.

Intellectual-capital scholarship developed frameworks for identifying and measuring intangible resources located in human capacities, organizational structures, routines, relationships, and knowledge systems. Bontis, for example, develops measures connecting dimensions of intellectual capital with organizational performance [3]. The literature therefore expands the capital concept beyond physical and financial assets toward knowledge-intensive resources distributed within an organization.

This tradition is relevant in two respects. First, it recognizes that valuable knowledge resources can reside in different organizational locations. Knowledge held by employees differs from organizational routines, databases, procedures, or external relationships. Second, the literature treats relations among such resources as consequential for organizational performance.

The present framework shifts the primary dependent variable from organizational performance toward subsequent epistemic generativity. An epistemic resource qualifies provisionally as knowledge capital when its possession, access, or control changes the conditions, rate, range, direction, or combinatorial possibilities of later knowledge generation. This criterion can include organizationally valuable resources while also extending to public, non-commercial, individual, communal, and inter-institutional contexts.

Intellectual-capital scholarship therefore contributes an important vocabulary of intangible productive resources, while knowledge-capital expansion focuses on their recursively generative consequences.

2.11 Forms and Conversion of Capital in Bourdieu

This subsection examines Bourdieu's extension of capital across economic, cultural, and social forms. Its role is to establish a theoretical basis for cross-capital conversion, embodied accumulation, path dependence, and unequal capacity arising from historically accumulated resources.

Bourdieu characterizes capital as accumulated labor and emphasizes the temporal inertia produced by accumulation [4]. Economic capital, cultural capital, and social capital can exist in different forms and can, under specified conditions, be converted into one another. Cultural capital can be embodied through long processes of acquisition, objectified in cultural goods, or institutionalized through credentials. Social capital is associated with durable networks and the resources accessible through them.

Several features of this framework are highly relevant to knowledge-capital expansion. Capital takes time to accumulate, previously accumulated capital changes subsequent possibilities, and different forms of capital can be converted. These features support analysis of recursive trajectories in which epistemic resources contribute to reputation, networks, credentials, institutional access, or financial resources that subsequently contribute to further epistemic generation.

Bourdieu also strengthens the analysis of capitalization asymmetry. Individuals encountering an identical publicly available resource can bring different embodied cultural capital, social connections, institutional credentials, and economic resources to its use. Equal exposure to a resource therefore occurs within historically unequal distributions of convertible capital.

The present framework extends this insight through an explicit generative criterion. The central question concerns how heterogeneous capital configurations alter an actor's capacity to convert shared epistemic resources into further knowledge production. Cross-capital conversion thereby becomes a mechanism within recursive knowledge-capital expansion.

2.12 Cumulative Advantage in the Sociology of Science

This subsection reviews cumulative-advantage theory in the sociology of science. Its objective is to locate recursive epistemic advantage within an established account of how scientific recognition and resources become self-reinforcing over time.

Merton's analysis of the Matthew effect examines differential allocation of recognition in science and develops the broader concept of cumulative advantage [14]. Initial differences in recognition, institutional location, resources, or opportunity can influence access to subsequent advantages. Scientific careers and institutions can therefore follow divergent trajectories through feedback mechanisms that amplify earlier differences.

This literature is closely related to the present concept of recursive epistemic advantage. Both frameworks focus on temporally extended processes in which prior states influence subsequent possibilities. Their primary analytical objects differ. Cumulative-advantage research commonly emphasizes recognition, reward, resources, institutional prestige, and career opportunities. Knowledge-capital expansion additionally examines epistemic resources themselves as inputs into future generative capacity.

The distinction can be illustrated through a conceptual resource. Learning a new formalism can increase a researcher's ability to understand later literature, formulate questions, connect domains, and acquire further knowledge. The resulting advantage can emerge before any external recognition occurs. If the new knowledge later produces publication, reputation, funding, or collaboration, epistemic expansion and sociological cumulative advantage can enter a coupled feedback process.

Merton's framework therefore provides an essential neighboring theory for the social amplification of advantage, while the present inquiry extends recursive analysis into the internal and relational conditions of epistemic generation.

2.13 Knowledge Commons and Commons Governance

This subsection reviews knowledge-commons scholarship as the principal literature for understanding shared epistemic resources, institutional arrangements, access, and enclosure. Its objective is to establish the commons-side of the theoretical problem before examining unequal capitalization from public resources.

Hess and Ostrom develop knowledge commons as a framework for studying knowledge as a shared resource and for analyzing the institutional arrangements through which such resources are created, maintained, accessed, governed, and protected [9]. Their volume addresses digital knowledge, scholarly communication, intellectual property, open access, collaborative communities, libraries, preservation, and possible enclosure.

Knowledge differs from many natural-resource commons because informational resources frequently display low rivalry in use. Reading an open article does not consume the article's informational content for subsequent readers. Digital reproduction can further reduce marginal distribution costs. These properties enlarge the potential for broad circulation while leaving questions of exclusion, preservation, infrastructure, attribution, legal rights, and governance intact.

The knowledge-commons literature provides the institutional foundation for the present paper's concept of public knowledge as generative infrastructure. Public epistemic resources can serve as inputs into multiple independent generative processes. The same article, dataset, codebase, archive, or concept can contribute to future work by many actors.

The present inquiry adds capitalization capacity as a separate analytical dimension. Governance of access determines whether a resource can be reached and used under specified conditions. Capitalization analysis asks how differently positioned actors transform that accessible resource into subsequent generative capacity. The two problems are complementary. A highly open commons can remain heterogeneous in the generative gains that different actors derive from it.

This distinction forms the basis of the later openness–concentration problem. The aggregate generativity of a commons can increase while effective knowledge-generating capacity becomes increasingly concentrated among actors with stronger complementary resources.

2.14 Academic Capitalism and Institutional Knowledge Production

This subsection reviews academic-capitalism scholarship as an account of the institutional organization and market orientation of knowledge production. Its objective is to connect individual knowledge-capital

trajectories with universities, intellectual property, commercialization, and organizational circuits linking public and private resources.

Slaughter and Rhoades analyze an academic capitalist knowledge and learning regime in which universities, academic actors, states, and markets become connected through new organizational structures and circuits of knowledge creation and commercialization [18]. Their framework examines patents, copyrights, educational markets, institutional policies, administrative capacities, and networks that connect higher education to commercial activity.

This literature is especially relevant to the distinction between epistemic production and control over conditions of epistemic production. Universities can provide laboratories, databases, salaries, grants, credentials, legal offices, publication infrastructure, and networks through which knowledge is generated and circulated. Institutional control over these conditions can shape research agendas, access to resources, ownership of outputs, and conversion of research into other forms of capital.

Academic-capitalism research also illustrates commons-to-private conversion. Public funding, publicly accumulated scientific knowledge, university infrastructure, and collective epistemic labor can participate in processes that generate privately appropriable intellectual property or commercial returns. The normative status of such arrangements depends upon their specific institutional and distributive structures, yet their existence demonstrates the importance of tracing epistemic value across multiple stages of production and circulation.

The present inquiry extends this analysis through recursive capacity. The question concerns how institutional returns from one cycle can alter control over generative conditions in subsequent cycles and thereby change the future distribution of knowledge-producing capacity.

2.15 Platform Capitalism and Infrastructural Control

This subsection extends the institutional analysis toward digital infrastructure. Its objective is to examine how control over platforms can shape access, coordination, data accumulation, dependency, and productive possibilities across large populations of users.

Srnicek's account of platform capitalism analyzes platforms as business forms that provide digital infrastructures through which other actors interact and operate [20]. Platforms can occupy intermediary positions, collect data, organize markets, exploit network effects, and build infrastructural dependencies across economic sectors.

The relevance to epistemic production extends beyond commercial platforms in a narrow sense. Contemporary knowledge production increasingly depends upon search engines, scholarly databases, cloud computing, model providers, repositories, social platforms, publication systems, collaborative software, and computational services. Control over such infrastructures can influence which epistemic resources become discoverable, processable, circulable, and economically feasible to use.

This produces a form of power located in generative conditions. An actor can influence knowledge production through control of the infrastructure on which other actors depend, even when the infrastructure owner does not perform the underlying epistemic labor. The distinction becomes particularly important for AI systems, where model access, compute, proprietary data, interfaces, and agentic infrastructure can mediate large portions of the epistemic production process.

Platform-capitalism scholarship therefore contributes an infrastructural dimension to knowledge-capital analysis. It directs attention toward control over the environments within which capitalization occurs.

2.16 Epistemic Injustice and Unequal Epistemic Participation

This subsection introduces epistemic-injustice scholarship as a normative and social-epistemological account of power within practices of knowing. Its role is to broaden inequality analysis beyond unequal possession of resources toward unequal standing, interpretive capacity, recognition, and participation within epistemic relations.

Fricker's *Epistemic Injustice* develops testimonial injustice and hermeneutical injustice as forms of wrong connected to a person's capacity as a knower [6]. Testimonial injustice concerns credibility deficits associated with prejudice, while hermeneutical injustice concerns structural disadvantages in the collective interpretive resources available for understanding and communicating social experience.

The present paper addresses a different object, yet the connection is substantial. Capitalization capacity depends partly upon whether actors can participate effectively in epistemic systems. Access to information has limited generative value when an actor's testimony is systematically discounted, when relevant conceptual resources are unavailable, or when institutional arrangements exclude an actor from recognized channels of knowledge production.

Epistemic injustice also reveals that epistemic resources have social conditions of recognition. Knowledge production involves credibility, classification, interpretation, and institutional uptake. These processes can affect whether an epistemic contribution becomes visible, reusable, citable, fundable, or convertible into future opportunities.

The literature therefore adds a justice-sensitive dimension to capitalization asymmetry. Unequal epistemic generativity can arise through distributions of material resources and through unequal relations of recognition and interpretation.

2.17 Generative Justice and Value Circulation

This subsection reviews generative justice as the principal normative interlocutor for the later concepts of generative extraction, generative return, and recirculation. Its objective is to shift attention from the final distribution of outputs toward the trajectories through which value is generated, extracted, circulated, and returned.

Eglash develops generative justice around the circulation of value to the people and systems from which that value originates [5]. The framework is concerned with forms of value that include economic, ecological, and social dimensions and with systems that support recursive circulation rather than one-directional extraction.

This orientation is especially useful for a knowledge commons. Public knowledge can enter the generative process of an actor, contribute to new epistemic outputs, and increase the actor's subsequent productive capacity. The resulting value can then follow different trajectories. It can remain privately controlled, become institutionally enclosed, return to public circulation, support the source community, create new shared infrastructure, or combine several of these pathways.

Generative justice therefore provides a basis for distinguishing asymmetric capitalization from stronger normative categories. Unequal gains from a shared resource establish an asymmetry. A generative-extraction analysis additionally examines flows between a source field and the actor who capitalizes upon it. A theory of exploitation would require further criteria concerning power, dependency, degradation, suppression of future generativity, or other normatively significant relations.

The present foundational paper leaves those thresholds open while adopting value circulation and regeneration as essential variables for later ethical analysis.

2.18 Artificial Intelligence and Contemporary Scientific Production

This subsection reviews artificial intelligence as a contemporary development in the means of epistemic production. Its objective is to identify changes in scale, automation, search, recombination, and research infrastructure that can amplify mechanisms already identified in the preceding literatures.

The OECD's *Artificial Intelligence in Science* surveys current and potential applications of AI across scientific research and emphasizes their possible effects on scientific productivity, discovery, research infrastructure, and research governance [15]. AI can assist literature processing, pattern identification, modeling, experimentation, prediction, and other stages of scientific activity. The report also emphasizes differences in access and the importance of infrastructure and policy.

From the perspective of knowledge-capital expansion, AI can alter *epistemic absorption capacity*: the quantity and diversity of external epistemic resources that an actor can practically search, process,

compare, and recombine within a given period. Public availability can therefore acquire different practical significance when machine assistance changes the cost of capitalizing upon a large corpus.

AI can also alter the organization of epistemic labor. Search, translation, classification, summarization, candidate generation, drafting, comparison, and some forms of evaluation can be distributed across machine systems. Large computational infrastructures can parallelize these processes. The relationship between direct human epistemic labor and total epistemic output can consequently change.

These developments connect AI to several earlier literatures simultaneously. Human-capital theory raises questions concerning complementarity between trained persons and computational tools. R&D-based knowledge-capital research raises productivity questions. Cumulative-advantage theory raises questions about recursively amplified access. Knowledge-commons research raises questions about capitalization of public inputs. Platform capitalism raises questions concerning infrastructural control. Academic capitalism raises questions concerning institutional appropriation. Generative justice raises questions concerning circulation and return.

AI therefore serves as a particularly dense contemporary case of knowledge-capital expansion. Its dedicated political economy requires a separate inquiry, while the present foundational paper uses it to demonstrate the relevance of the broader conceptual architecture.

2.19 Literature Synthesis and Analytical Positioning

This subsection synthesizes the reviewed traditions and specifies the analytical position of the present inquiry. The synthesis proceeds by distinguishing the principal object addressed by each literature and then identifying relations that remain insufficiently integrated across them.

Classical political economy establishes capital accumulation and distribution as central economic problems. Marxian political economy provides a dynamic account of valorization, reproduction, accumulation, concentration, and centralization while locating the capitalist within historically specific relations of production. Later Marxist scholarship broadens accumulation analysis across social, spatial, and institutional environments.

Kantian epistemology contributes a distinct concern with conditions of cognition. Economics of knowledge and information establishes knowledge as an object of production, dissemination, innovation, and growth. Human-capital theory analyzes investment in embodied productive capacities. R&D-based knowledge-capital research operationalizes accumulated research investment in productivity models. Intellectual-capital scholarship classifies intangible organizational resources. Bourdieu develops historically accumulated and convertible forms of capital across economic, cultural, and social domains.

The sociology of science identifies cumulative-advantage mechanisms through which initial differences can become self-reinforcing. Knowledge-commons scholarship analyzes shared epistemic resources and the institutional conditions governing access, preservation, circulation, and enclosure. Academic-capitalism research studies market-oriented institutional configurations of knowledge production. Platform-capitalism scholarship foregrounds infrastructural control and dependency. Epistemic-injustice theory analyzes power within epistemic recognition and interpretive participation. Generative justice emphasizes value circulation and regeneration. Contemporary AI research demonstrates rapidly changing technical capacities for scaling and reorganizing epistemic production.

The present inquiry draws these literatures together around a specific theoretical object: the recursive transformation of epistemic resources into future epistemic generative capacity under conditions of public knowledge. Several analytical distinctions follow from this positioning.

First, *knowledge capital* is defined through generative consequence. An epistemic resource becomes capital-like when its possession, access, or control alters the conditions, rate, range, direction, or combinatorial possibilities of subsequent knowledge generation. This definition permits propositions, questions, conceptual distinctions, methods, data, tools, trained capacities, relational resources, and infrastructures to be examined within a common generative framework while preserving their heterogeneous properties.

Second, *knowledge-capital expansion* designates a dynamical structure. The object of analysis includes recursive accumulation, second-order changes in generative capacity, cross-domain recombina-

tion, question-space expansion, cross-capital conversion, feedback, concentration, and other mechanisms through which previous epistemic generation changes subsequent generative possibilities.

Third, *capitalization capacity* distinguishes public availability from productive conversion. Two actors can encounter the same epistemic resource and derive different changes in future generativity because their prior epistemic resources, time, languages, institutional access, networks, funding, infrastructure, and other complementary conditions differ. This relation is described as capitalization asymmetry.

Fourth, the framework separates the dynamics of expansion from positions within relations of epistemic production. A high rate of knowledge-capital expansion describes a trajectory. A knowledge capitalist describes a relational position associated with control over significant means and conditions of epistemic production. The corresponding analytical dimensions can therefore vary independently. This separation adapts a distinction already visible in Marxian political economy between the movement of capital and the social bearer of capitalist functions.

Fifth, public knowledge is treated as generative infrastructure. A commons supplies resources that can enter many subsequent epistemic processes. Openness can increase field-level generativity while heterogeneous capitalization capacities create divergent recursive gains. This possibility motivates the later concept of an openness–concentration paradox.

Sixth, knowledge capital can participate in conversion across other forms of capital. Epistemic production can generate reputation, networks, credentials, funding, institutional position, visibility, and infrastructure. These returns can subsequently modify the conditions of further epistemic generation. Knowledge-capital expansion can therefore participate in coupled, multi-capital feedback processes.

Seventh, accumulation, appropriation, extraction, enclosure, and capitalist position require separate analytical treatment. The existence of recursive expansion establishes a dynamic property. Its political, ethical, and legal character depends upon additional relations concerning productive conditions, labor, control, circulation, dependency, recognition, ownership, and regeneration.

The literature therefore supplies substantial components of the proposed framework while leaving a space for their integration. The present paper develops that integration as a foundational inquiry into how publicly available epistemic resources can become recursively productive, how the capacity for such capitalization becomes unevenly distributed, how epistemic accumulation interacts with other forms of capital, and how expansion dynamics relate to positions within the relations governing knowledge production. Sections 3–8 develop these concepts systematically before the Discussion considers their broader theoretical, ethical, and jurisprudential implications.

3 Conceptual Foundations of Knowledge Capital

This section develops the conceptual vocabulary required for the subsequent analysis of knowledge-capital expansion. Its role is to translate the literature reviewed in Section 2 into a coherent analytical framework centered on epistemic generativity. The section proceeds from epistemic resources and their generative consequences to the concepts of knowledge capital, knowledge-capital expansion, epistemic capitalization, capitalization capacity, and recursive epistemic advantage. It then extends the framework to questions and inquiry possibility spaces, clarifies the limits of the capital analogy, and concludes by distinguishing dynamic properties of knowledge-capital expansion from relational positions within epistemic production. The definitions introduced here remain provisional and are intended to support comparison, refinement, and later empirical operationalization.

3.1 Epistemic Resources and Generative Consequence

This subsection defines the broad class of resources that can enter epistemic production and introduces generative consequence as the criterion by which an epistemic resource becomes relevant to the present framework. The objective is to avoid reducing knowledge capital to codified propositions or measurable information stocks while preserving a sufficiently restrictive criterion for analytical use.

An *epistemic resource* is provisionally understood as a resource that can participate in the acquisition, interpretation, production, revision, organization, communication, or extension of knowledge. Such resources can include propositions, concepts, distinctions, questions, methods, data, archives, languages, instruments, software, trained capacities, models, repositories, and other resources that enter epistemic activity.

The category is intentionally heterogeneous. A mathematical theorem and a laboratory instrument have different ontological and functional properties. A research question differs from a dataset, and an embodied interpretive skill differs from a public archive. Their inclusion within a common analytical category does not imply functional equivalence. The relevant commonality lies in their possible contribution to subsequent epistemic generation.

The present framework therefore adopts *generative consequence* as its principal criterion. An epistemic resource has generative consequence when its availability, possession, access, or control changes the conditions under which subsequent epistemic production can occur. Such change can affect the rate, range, direction, cost, feasibility, or combinatorial structure of later inquiry.

This criterion distinguishes generatively consequential resources from resources whose epistemic relevance remains inert within a particular trajectory. A publicly available article, for example, may remain outside an actor’s effective epistemic process because the actor lacks the language, conceptual background, time, technical capacity, or institutional access needed to use it. The same article can become highly generative for another actor whose prior resources permit integration into ongoing inquiry.

Generative consequence is therefore relational and conditional. Its analytical unit is the interaction among an epistemic resource, an actor or system, and the conditions within which the resource becomes operative. This relation provides the foundation for the concepts developed throughout the remainder of the section.

3.2 Knowledge Capital

This subsection introduces the paper’s provisional definition of *knowledge capital*. Its role is to identify the subset of epistemic resources that participate in future-oriented generative processes and to distinguish this category from ordinary knowledge possession, information availability, and previously established expenditure-based measures of knowledge capital.

Knowledge capital consists of epistemic resources whose possession, access, or control modifies the conditions, rate, range, direction, or combinatorial possibilities of subsequent knowledge generation. The defining property is therefore generative consequence across time.

The term *capital* is used here in a restricted analytical sense. The concept does not imply that every form of knowledge should be assigned an economic price, treated as property, or understood through capitalist social relations. The term identifies a specific structural feature: an epistemic resource generated or acquired in one period can become a productive condition for further epistemic generation in a later period.

A minimal representation of this relation is given in Equation 11.

$$K_t \longrightarrow G_{t+1} \longrightarrow K_{t+1}, \quad (11)$$

where K_t denotes epistemic resources available at time t , and G_{t+1} denotes the generative capacity through which subsequent epistemic resources can be produced.

Equation 11 expresses a directional analytical relation rather than a deterministic law. An increase in epistemic resources can fail to increase generative capacity, and some resources can reduce or distort subsequent generativity. Knowledge capital therefore refers to the generatively operative portion of an epistemic configuration under specified conditions.

This definition is broader than R&D-based knowledge-capital measures reviewed in Subsection 2.9. It can include expenditure-based research stocks while also extending to questions, conceptual distinctions, public archives, methods, relational resources, and infrastructures whose generative effects arise through mechanisms that cannot be reduced to accumulated research expenditure.

The concept is also broader than individual human capital. Knowledge capital can be embodied in persons, distributed across groups, encoded in public repositories, embedded in institutions, instantiated in infrastructures, or formed through relations among multiple actors. The analytical category therefore permits later comparison across individual, collective, institutional, and infrastructural levels.

3.3 Knowledge-Capital Expansion

This subsection defines *knowledge-capital expansion* as the central dynamical object of the paper. Its objective is to distinguish recursive growth in epistemic generativity from simple accumulation of informational quantity.

Knowledge-capital expansion is the process through which accumulated epistemic resources enlarge subsequent knowledge-generating capacity and thereby contribute to the production of additional epistemic resources capable of entering later generative cycles.

The central feature is recursion. An epistemic output can become a productive input for subsequent epistemic activity. A method learned during one inquiry can accelerate the next. A conceptual distinction can make new questions visible. A dataset assembled for one project can support several later projects. A cross-disciplinary connection can generate a new field of inquiry. The result of one generative cycle can therefore change the structure of the next.

Knowledge-capital expansion consequently differs from a linear model in which knowledge merely increases through successive additions. Linear accumulation can be expressed informally as $K_{t+1} = K_t + \Delta K_t$. Knowledge-capital expansion additionally concerns changes in the generative function through which ΔK itself becomes possible.

The concept also remains broader than any single Marxian mechanism reviewed in Subsections 2.2 and 2.4. Knowledge-capital expansion can contain processes analogous to accumulation, reproduction, conversion, concentration, or centralization, while preserving the distinctions among their specific causal structures.

The term *expansion* therefore designates a family of trajectories rather than a single mechanism. Sections 4 and 6 later differentiate the principal mechanisms and relational configurations through which such trajectories can emerge.

3.4 Epistemic Generativity

This subsection defines *epistemic generativity* as the capacity through which epistemic resources can be produced, transformed, recombined, or made available for further inquiry. Its role is to provide the intermediate concept linking existing epistemic resources with later knowledge-capital expansion.

Epistemic generativity refers to the capacity of an actor, collective, system, or institutional configuration to generate subsequent epistemic resources. The concept includes more than output volume. Generativity can concern the capacity to formulate questions, identify distinctions, construct methods, interpret evidence, generate hypotheses, connect domains, revise previous positions, or create infrastructures that support later inquiry.

The framework therefore separates epistemic state from epistemic generativity. Two actors can possess similar amounts of codified knowledge while differing substantially in their capacity to generate further questions, synthesize fields, interpret anomalies, or construct new methods. Conversely, actors with different knowledge stocks can possess comparable generative capacities within particular domains.

Epistemic generativity is also conditional upon generative conditions. Material resources, time, language, cognitive capacity, institutional access, social relations, technical infrastructure, and prior epistemic resources can all influence whether potential generativity becomes practically realizable.

This conditional structure becomes important when the framework moves from individual knowledge accumulation to the political economy of epistemic production. Control over the conditions of generativity can influence future knowledge production even when direct control over completed knowledge outputs is limited.

3.5 Epistemic Capitalization

This subsection introduces *epistemic capitalization* as the process that connects accessible epistemic resources with changes in future generative capacity. Its objective is to distinguish formal access from productive conversion.

Epistemic capitalization is the process through which an epistemic resource is converted into enhanced capacity for subsequent epistemic generation. The concept concerns transformation rather than possession alone.

A publicly accessible book provides a simple illustration. Formal access makes the book available as an epistemic resource. Capitalization occurs when the resource becomes integrated into an actor's generative organization in a way that alters later inquiry. The book can introduce a formalism, distinction, historical case, vocabulary, or research problem that subsequently affects what the actor can understand, ask, compare, or produce.

Capitalization can also occur institutionally. A university can convert a shared scientific method into a new laboratory programme. A research group can convert an open dataset into a new model or benchmark. A digital platform can convert publicly produced information into proprietary infrastructural capabilities. These cases differ normatively and institutionally, while sharing the analytical structure of conversion from accessible epistemic resource to enhanced generative capacity.

Epistemic capitalization therefore becomes the immediate mechanism through which public knowledge can participate in knowledge-capital expansion. The concept also prepares the later distinction between capitalization, appropriation, and extraction. Productive conversion by itself does not determine the normative character of the resulting trajectory.

3.6 Capitalization Capacity

This subsection defines *capitalization capacity* as a property of the actor-resource-condition relation. Its role is to explain why equivalent access to public knowledge can yield markedly different generative effects.

Capitalization capacity is the capacity to convert accessible epistemic resources into new knowledge, questions, methods, capabilities, infrastructures, or other resources that improve subsequent epistemic generation.

Capitalization capacity depends upon complementary conditions. Prior knowledge can determine whether a resource is intelligible. Language can determine whether a text is usable. Time can determine whether a resource can be studied. Institutional access can determine whether related data or tools are available. Financial resources can determine whether an experiment can be performed. Computational infrastructure can determine whether a publicly available model or dataset can be processed at useful scale.

The concept therefore gives analytical form to the distinction between public availability and effective use. Formal accessibility concerns the legal, technical, or practical ability to reach a resource. Capitalization capacity concerns the ability to integrate that resource into a subsequent generative cycle.

Capitalization capacity can itself become recursively cumulative. Successful capitalization can produce knowledge, reputation, funding, networks, infrastructure, or other resources that increase the capacity to capitalize on future epistemic inputs. This recursive possibility motivates the concepts of capitalization asymmetry and recursive epistemic advantage developed below.

3.7 Capitalization Asymmetry

This subsection develops *capitalization asymmetry* as the principal concept for analyzing heterogeneous generative returns under shared epistemic access. Its objective is to distinguish equality of availability from equality of generative consequence.

Capitalization asymmetry occurs when actors facing the same or substantially similar accessible epistemic resources experience different changes in their subsequent generative capacities because their

complementary conditions differ.

The basic relation is represented in Equation 12.

$$\Delta G_A(C) \neq \Delta G_B(C), \quad (12)$$

where C denotes an accessible epistemic resource or commons condition, and $\Delta G_A(C)$ and $\Delta G_B(C)$ denote the corresponding changes in generative capacity for actors A and B .

Equation 12 does not specify the cause of the difference. The asymmetry can arise from prior knowledge, education, language, time, institutional position, social networks, funding, computational resources, publication access, interpretive frameworks, or other generative conditions.

Capitalization asymmetry also does not imply injustice by itself. Differences in generative effect can arise through heterogeneous interests, histories, skills, or research directions without producing extractive or subordinating relations. Normative analysis requires additional information concerning access, power, appropriation, dependency, circulation, and effects on future generativity.

The concept nevertheless has substantial political-economic significance. When capitalization capacity is itself recursively reproduced, small differences in initial conditions can become persistent or amplified differences in later knowledge-generating capacity.

3.8 Recursive Epistemic Advantage

This subsection introduces *recursive epistemic advantage* as the dynamic consequence of repeated successful capitalization. Its role is to connect capitalization asymmetry with cumulative trajectories while distinguishing epistemic generative advantage from external recognition alone.

Recursive epistemic advantage is an advantage that increases an actor's capacity to capitalize upon subsequent epistemic resources. The relevant gain therefore affects future conversion capacity in addition to current epistemic output.

The process can involve several pathways. Acquired knowledge can make later knowledge easier to understand. A new method can reduce the cost of subsequent research. A successful paper can generate reputation that improves access to collaborators. A grant can produce infrastructure that enables new empirical work. A network can provide early access to emerging questions. A software tool can automate tasks that previously consumed substantial research time.

Recursive epistemic advantage consequently overlaps with the cumulative- advantage mechanisms reviewed in Subsection 2.12, while extending the object toward changes in epistemic productive capacity itself. Recognition and institutional advantage can contribute to the process, yet recursive epistemic advantage can also arise through changes that remain internal to an actor's capacity for understanding, questioning, or recombination.

This distinction becomes important for later cross-capital analysis. Epistemic advantage can generate non-epistemic resources, and those resources can return to the epistemic process as enlarged generative conditions.

3.9 Questions as Epistemic Resources

This subsection extends the framework beyond completed propositions by treating questions as potentially generative epistemic resources. Its objective is to capture forms of epistemic accumulation that expand future inquiry before a stable answer is available.

A research question can alter the organization of an epistemic field. It can identify an unrecognized variable, reveal a missing comparison, connect previously separate literatures, expose a conceptual ambiguity, motivate a new dataset, generate a methodological requirement, or create a sequence of further questions.

The epistemic value of a question therefore does not depend exclusively upon the existence of an immediate answer. Its generative consequence can lie in the new possibilities of inquiry that it creates.

Questions can also accumulate. Previous knowledge can improve the capacity to formulate more precise or more generative questions. Those questions can in turn guide the acquisition of new knowledge. Epistemic production therefore contains a recursive relation between accumulated knowledge and the space of future questioning.

This structure is especially relevant to interdisciplinary inquiry. Knowledge of multiple domains can reveal relational questions that remain invisible within each domain separately. The resulting question can become a productive resource whose principal effect is to reorganize the future search space.

3.10 Inquiry Possibility Spaces

This subsection introduces *inquiry possibility space* as a conceptual device for representing the range of questions, methods, comparisons, and epistemic trajectories that become available under a given configuration of resources and conditions. Its role is to give analytical form to the generative significance of questions and conceptual recombination.

Let Ω_t denote the set or structured space of epistemic trajectories that are practically available to an actor or system at time t . The formation of a new question can modify this space by introducing previously unavailable directions of inquiry.

A minimal representation is given in Equation 13.

$$K_t \longrightarrow Q_{t+1} \longrightarrow \Omega_{t+1} \longrightarrow K_{t+1}, \quad (13)$$

where Q_{t+1} denotes a newly available question and Ω_{t+1} denotes the resulting change in the possibility space of subsequent inquiry.

Equation 13 is schematic. The possibility space need not be represented as a formally enumerable set, and the framework does not assume that all epistemic trajectories are known in advance. The concept is used to describe changes in what can plausibly be asked, investigated, combined, or recognized from a given epistemic position.

Inquiry possibility spaces are also actor-dependent. The same public resource can expand one actor's inquiry possibilities substantially while producing little change for another actor. The concept therefore links question-space expansion directly to capitalization capacity and asymmetry.

3.11 Cross-Domain Generativity

This subsection develops cross-domain generativity as a further source of knowledge-capital expansion. Its objective is to capture productive effects that arise from relations among previously separated epistemic resources.

Knowledge accumulated across multiple domains can generate possibilities that are unavailable within each domain independently. A mathematical formalism can become a conceptual resource in social science. A legal distinction can alter the framing of a governance problem. A physical model can provide a heuristic for thinking about institutional dynamics. Historical knowledge can reveal assumptions hidden within a contemporary technical framework.

The generative effect therefore depends partly upon relations among resources. The value of an additional epistemic resource can vary according to the configuration into which it enters. A concept that has limited consequence in one epistemic environment can become highly generative when combined with resources from another domain.

Cross-domain generativity consequently introduces a combinatorial component into knowledge-capital expansion. Accumulation can increase the number of available resources while also increasing the number and diversity of possible relations among them.

This mechanism helps explain why epistemic expansion can display nonlinear features. The productive consequence of acquiring an additional resource can depend upon a previously accumulated configuration rather than upon the resource in isolation.

3.12 Boundaries of the Capital Analogy

This subsection specifies the conceptual boundaries of the capital analogy. Its objective is to prevent the framework from treating every useful form of knowledge as capital and to preserve distinctions between epistemic generativity and historically specific economic relations.

The capital analogy is analytically appropriate when an epistemic resource participates in a recursive process through which previous acquisition or generation changes the conditions of subsequent epistemic production. The analogy is weaker when a resource merely exists, is passively possessed, or produces no meaningful change in future generative capacity.

Several further limits follow.

First, knowledge capital does not imply economic valuation. Epistemic resources can have generative consequence without market exchange or monetary return.

Second, knowledge capital does not imply private ownership. Public-domain knowledge, open data, shared concepts, and communal epistemic resources can function as knowledge capital for many actors simultaneously.

Third, knowledge capital does not imply rivalry. The same epistemic resource can participate in multiple generative cycles without being exhausted through use.

Fourth, knowledge-capital expansion does not imply capitalist social relations. Recursive expansion can occur in public, cooperative, communal, individual, institutional, commercial, or mixed settings.

Fifth, generative consequence is context-dependent. A resource can function as knowledge capital for one actor or period and remain generatively inert in another.

The capital analogy therefore serves as a relational and dynamical analytical device. Its usefulness depends upon preserving the distinctions among resource, capacity, process, ownership, control, accumulation, and social position.

3.13 Dynamic Properties and Relational Positions

This subsection establishes the foundational distinction between knowledge-capital expansion and positions within relations of epistemic production. Its role is to connect the conceptual framework developed in this section with the political-economic analysis developed later in Section 6.

Knowledge-capital expansion is a dynamic property. It describes trajectories in which epistemic resources are generated, accumulated, recombined, converted, or reproduced in ways that alter future generative capacity. Its relevant variables include rate of expansion, recursive feedback, path dependence, capitalization capacity, recombination, concentration, and cross-capital conversion.

A knowledge capitalist is a relational position. The category concerns an actor's location within a structure of epistemic production, especially the actor's relation to means and conditions of production, epistemic labor, infrastructure, access, organizational authority, appropriation, and future generative conditions.

The distinction can be represented compactly as Equation 14.

$$\text{knowledge-capital expansion} \not\equiv \text{knowledge-capitalist position.} \quad (14)$$

Equation 14 expresses logical independence rather than empirical separation. Expansion dynamics and relational positions can interact strongly. Control over infrastructure can accelerate expansion, and accumulated epistemic capital can be converted into greater control over productive conditions. The analytical distinction is required because neither dimension determines the other by definition.

A researcher can therefore exhibit strong recursive knowledge-capital expansion while circulating outputs publicly and exercising little control over other epistemic producers. An institution can control substantial means of epistemic production while the individuals exercising organizational control possess limited embodied knowledge of the underlying research. A commons-oriented actor and a proprietary actor can display similar expansion dynamics while differing substantially in circulation, control, appropriation, and enclosure.

This distinction also clarifies the paper’s treatment of accumulation. Accumulation describes a process through which resources increase or become available for later productive cycles. Capitalist position describes a relation through which control, labor, appropriation, and generative conditions are organized. The political character of knowledge-capital expansion therefore depends upon the relational structures through which expansion is produced and governed.

The remainder of the paper develops these two dimensions separately before bringing them together. Section 4 examines the principal dynamics of expansion. Section 5 examines the conditions created by public knowledge and unequal capitalization capacity. Section 6 then analyzes relations of epistemic production, including control over generative conditions, knowledge-capitalist position, epistemic proletariat, dependency, appropriation, and extraction.

4 Dynamics of Knowledge-Capital Expansion

This section develops the dynamical dimension of knowledge-capital expansion introduced in Section 3. Its objective is to identify the principal mechanisms through which epistemic resources acquired or generated in one stage can modify subsequent generative capacity. The analysis proceeds from accumulation and reproduction to second-order generativity, recursive capitalization, question-space expansion, combinatorial and cross-domain effects, path dependence, cross-capital conversion, epistemic throughput, and coupled feedback structures. The section treats these mechanisms as analytically distinguishable processes that can coexist within a single epistemic trajectory. Their institutional and relational organization is examined separately in Sections 5 and 6.

4.1 Accumulation and Reproduction

This subsection establishes accumulation and reproduction as the most elementary temporal mechanisms of knowledge-capital expansion. Its role is to distinguish an increase in available epistemic resources from reproduction of the conditions through which those resources continue to generate further epistemic activity.

Epistemic accumulation occurs when resources generated, acquired, preserved, or organized during one period remain available for subsequent inquiry. Such resources can include propositions, concepts, questions, methods, datasets, archives, software, instruments, linguistic competence, trained judgment, and relations that support later knowledge production. Accumulation therefore creates temporal continuity between epistemic states.

A simple stock representation can describe an increase in available resources through $K_{t+1} = K_t + \Delta K_t$. This expression captures quantitative addition, while knowledge-capital expansion requires attention to the consequences of the accumulated configuration for subsequent production.

Reproduction concerns persistence of the generative process itself. An epistemic system reproduces its generative capacity when it preserves or recreates sufficient conditions for continued inquiry. These conditions can include access to previous outputs, interpretive capacities, methods, time, material infrastructure, institutional continuity, collaborative relations, and mechanisms of transmission.

The distinction between accumulation and reproduction is important because an epistemic archive can expand while the capacity to interpret or extend it deteriorates. Conversely, a community can reproduce highly effective generative practices with limited growth in codified output. Preservation of accumulated resources and reproduction of generative conditions therefore constitute separate dimensions of epistemic continuity.

The Marxian distinction between accumulation and reproduction reviewed in Subsection 2.4 provides an important conceptual precedent [13]. In the present framework, the analogy concerns the temporal relation between outputs of previous cycles and conditions of subsequent production. The underlying epistemic mechanisms remain specific to knowledge generation.

4.2 First-Order and Second-Order Generativity

This subsection distinguishes direct epistemic production from changes in the capacity for subsequent epistemic production. Its objective is to identify the recursive mechanism that gives knowledge-capital expansion its specifically capital-like character.

First-order generativity concerns the production of an epistemic output from an existing configuration of resources and conditions. A researcher can apply a known method to a dataset, derive a result, produce an interpretation, or formulate a new proposition. The immediate analytical object is the output generated in the current cycle.

Second-order generativity concerns change in the capacity for future generation. An epistemic output can modify the actor's methods, concepts, interpretive competence, question repertoire, infrastructure, or other productive conditions. The consequence therefore extends beyond the immediate output.

The relation between epistemic resources and second-order generativity is shown in Equation 15.

$$K_t \longrightarrow \Delta G_{t+1} \longrightarrow \Delta K_{t+1}. \quad (15)$$

Equation 15 represents a process in which existing epistemic resources contribute to a change in future generative capacity, which subsequently influences the production of further epistemic resources.

A new programming language provides a simple example. Immediate use of the language can produce one program, while mastery of the language can also alter the range of computational problems that become tractable in later work. A mathematical formalism can similarly produce an immediate derivation while also creating the capacity to recognize structures across later problems.

Second-order generativity provides the central transition from knowledge accumulation to knowledge-capital expansion. The relevant increase occurs in the productive consequences of accumulated resources across successive epistemic cycles.

4.3 Recursive Capitalization

This subsection develops recursive capitalization as the mechanism through which successful epistemic capitalization alters the conditions of later capitalization. Its role is to connect the conversion process defined in Subsection 3.5 with temporally extended trajectories.

A single act of epistemic capitalization converts an accessible resource into enhanced generative capacity. Recursive capitalization occurs when the result of that conversion becomes part of the conditions through which later resources are capitalized.

The recursive structure is shown in Equation 16.

$$K_t \longrightarrow G_{t+1} \longrightarrow K_{t+1} \longrightarrow G_{t+2} \longrightarrow K_{t+2}. \quad (16)$$

Equation 16 describes successive cycles in which accumulated epistemic resources influence subsequent generative capacity and thereby participate in the production of further resources.

Recursive capitalization can produce acceleration when later resources become easier to interpret, integrate, or combine because of previous accumulation. Familiarity with a theoretical literature can reduce the cost of understanding subsequent papers. Acquisition of a formal method can expand the set of later resources that become usable. Development of a reusable dataset or software framework can lower the marginal effort required for subsequent projects.

The process can also exhibit saturation, interruption, or decline. Additional resources can produce diminishing generative gains when they become redundant, exceed available attention, depend upon unavailable complementary resources, or remain disconnected from active inquiry. Recursive capitalization therefore describes a structural possibility whose trajectory depends upon the configuration of resources and conditions.

This feature distinguishes the framework from a model that assumes uniform returns to accumulated knowledge. The generative effect of an additional resource depends upon the state into which it enters.

4.4 Question-Space Expansion

This subsection analyzes expansion of the space of possible inquiry as a distinctive mechanism of knowledge-capital growth. Its objective is to show how epistemic accumulation can increase future possibilities through the generation of questions, distinctions, variables, and research directions.

Questions can emerge from accumulated knowledge when existing concepts reveal gaps, tensions, unexplained observations, or possible connections. The resulting question can reorganize inquiry before any answer exists. Its generative effect lies in the trajectories that become available through its formulation.

The recursive relation between knowledge and inquiry possibilities is represented in Equation 17.

$$K_t \longrightarrow Q_{t+1} \longrightarrow \Omega_{t+1} \longrightarrow K_{t+1}. \quad (17)$$

Equation 17 describes a process in which accumulated epistemic resources support formation of a question Q_{t+1} , which modifies the inquiry possibility space Ω_{t+1} and thereby guides subsequent knowledge generation.

Question-space expansion can occur through increasing resolution within an existing research programme. A broad question can generate narrower variables, distinctions, and empirical tests. It can also occur through conceptual displacement when a new question changes the structure of the problem itself.

The generative consequence of questions makes epistemic production partially option-generating. A productive inquiry can create future research options even when its current conclusions remain limited. This form of expansion is particularly important for foundational, interdisciplinary, and exploratory research, where the principal contribution can consist in making previously unavailable questions formulable.

Question-space expansion can also become recursive. Better questions can produce knowledge that supports formation of still more differentiated questions. The accumulation of epistemic capital therefore includes growth in the capacity to generate productive inquiry trajectories.

4.5 Combinatorial Expansion

This subsection develops combinatorial expansion as a mechanism arising from relations among accumulated epistemic resources. Its role is to explain why growth in generative capacity can depend upon the configuration of knowledge as well as the quantity of resources available.

An additional epistemic resource can interact with previously accumulated resources in multiple ways. A new concept can reinterpret earlier observations. A method can be applied to a dataset collected for another purpose. A historical case can challenge an abstract model. A formal distinction can connect two literatures that previously appeared unrelated.

The relevant generative object is therefore the configuration of resources and the possible relations among them. Accumulation increases the number of available epistemic elements, while combinatorial expansion can increase the number of productive relations among those elements.

For epistemic domains A , B , and C , a possible super-additive generative effect is represented in Equation 18.

$$G(K_A, K_B, K_C) > G(K_A) + G(K_B) + G(K_C). \quad (18)$$

Equation 18 represents a regime in which the combined configuration produces generative possibilities exceeding the sum of those available through each epistemic domain separately.

The inequality in Equation 18 is a conceptual representation. Empirical application would require domain-specific definitions of generative output and comparison. The analytical point concerns the possibility that relations among resources generate additional epistemic value.

Combinatorial expansion also introduces a selection problem. The number of possible combinations can grow faster than the capacity to evaluate them. Search, attention, judgment, and filtering therefore become increasingly important generative conditions as epistemic resources accumulate.

4.6 Cross-Domain Recombination and Transfer

This subsection examines movement of epistemic resources across disciplinary or conceptual domains. Its objective is to distinguish direct transfer from recombination and to identify cross-domain circulation as a potential source of recursive expansion.

Cross-domain transfer occurs when an epistemic resource developed in one domain becomes usable in another. Mathematical methods can enter economics, physical models can inform network analysis, legal concepts can enter governance research, and historical methods can reshape interpretation of contemporary institutions.

Recombination involves a stronger transformation. A resource entering a new domain can interact with local concepts, questions, evidence, or methods and produce a configuration that differs from its role in the source domain. The transferred resource can subsequently return to the source field in modified form.

A simple bidirectional trajectory is shown in Equation 19.

$$K_A \longrightarrow K_{A \rightarrow B} \longrightarrow K'_B \longrightarrow K'_A. \quad (19)$$

Equation 19 represents a resource originating in domain A , entering domain B , contributing to a transformed epistemic configuration K'_B , and later feeding back into a changed configuration K'_A .

Cross-domain transfer depends upon translation. Concepts often carry assumptions, scales, units of analysis, evidentiary standards, and ontological commitments specific to their original domain. Productive transfer therefore requires reconstruction of the conditions under which the resource remains meaningful and generative.

Successful recombination can produce substantial epistemic capital because a resource acquired for one purpose becomes reusable across several later domains. Interdisciplinary accumulation can consequently expand through increasing connectivity among epistemic resources.

4.7 Path Dependence and Recursive Advantage

This subsection develops path dependence as a temporal property of knowledge-capital expansion. Its objective is to explain how earlier epistemic states influence the range and cost of later trajectories and how recursive advantage can arise from historically accumulated configurations.

Epistemic development is path-dependent when the generative consequence of a current resource depends upon resources, decisions, relations, and capacities accumulated earlier in the trajectory. The same input can therefore produce different outcomes across actors with different histories.

Prior conceptual knowledge provides one mechanism. A technically advanced paper can be highly generative for a reader whose earlier training supplies the required mathematical and disciplinary background. The same paper can produce limited immediate generativity for a reader whose previous trajectory has developed other capacities.

Path dependence also operates through infrastructure and relations. An existing dataset can make a new question inexpensive to investigate. A long-term collaboration can lower coordination costs. A previously established reputation can facilitate access to experts or institutions. Earlier accumulation thereby alters the cost structure and feasibility of later epistemic activity.

Merton's theory of cumulative advantage provides an important sociological account of self-reinforcing differences in recognition and opportunity [14]. The present concept of recursive epistemic advantage extends the same temporal logic toward epistemic productive capacity. Prior advantages can affect the ability to understand, combine, question, and capitalize upon subsequent resources.

Path dependence also implies historical irreversibility in some trajectories. Time invested in one body of knowledge can create specialized capacities whose later value depends upon changes in the surrounding field. The dynamical analysis of knowledge capital therefore requires attention to sequences and histories in addition to current stocks.

4.8 Cross-Capital Conversion

This subsection analyzes conversion between epistemic capital and other forms of capital. Its role is to extend the dynamics beyond internally epistemic recursion and to identify feedback pathways linking knowledge, reputation, finance, networks, institutional position, and infrastructure.

Bourdieu’s account of convertible forms of capital provides an important theoretical precedent for this analysis [4]. In knowledge production, epistemic achievement can generate resources whose immediate form is social, institutional, reputational, or financial. These resources can subsequently return to the epistemic process.

A multi-capital configuration is represented in Equation 20.

$$\mathbf{C}_t = (K_t, R_t, F_t, N_t, S_t, I_t, \dots), \quad (20)$$

where K_t denotes epistemic capital, R_t reputational capital, F_t financial capital, N_t network capital, S_t status or institutional capital, and I_t infrastructural capital.

Equation 20 is a bookkeeping device for analytically distinguishing forms of accumulated resources. It does not imply commensurability among the components.

A recursive cross-capital pathway is shown in Equation 21.

$$K_t \longrightarrow R_{t+1} \longrightarrow F_{t+1} \longrightarrow I_{t+1} \longrightarrow G_{t+2} \longrightarrow K_{t+2}. \quad (21)$$

Equation 21 represents one possible sequence in which epistemic production contributes to reputation, reputation contributes to financial resources, financial resources support infrastructure, and infrastructure enlarges later epistemic generativity.

Other trajectories can operate through networks, credentials, institutional authority, visibility, or combinations of these resources. Conversion rates also depend upon institutional contexts. A publication can generate substantial reputation in one field and little reputational return in another. Reputation can produce funding in one institutional environment and primarily symbolic recognition in another.

Cross-capital conversion is therefore relationally mediated even when analyzed dynamically. Section 6 later examines the control structures through which such conversions become possible.

4.9 Epistemic Throughput and Capital Conversion

This subsection introduces epistemic throughput as a potentially consequential feature of contemporary knowledge production. Its objective is to distinguish the intrinsic generative significance of epistemic outputs from the institutional value that can arise through the volume, frequency, or visibility of production.

Epistemic throughput refers to the quantity of epistemic artifacts or candidate outputs that an actor or system can produce, process, evaluate, or circulate within a given period. Higher throughput can emerge through accumulated expertise, organizational scale, automation, computational infrastructure, division of labor, or combinations of these conditions.

Throughput can become capitalizable when institutions reward visible productivity. Publications, reports, datasets, software releases, citations, presentations, or other outputs can contribute to reputation, credentials, funding, network access, or institutional position. The production rate itself can therefore enter cross-capital conversion processes.

This possibility creates a distinction between epistemic value and throughput value. An output can contribute substantially to inquiry through conceptual or empirical significance. It can also contribute to an actor’s accumulation trajectory through its visibility, countability, timeliness, or compatibility with institutional reward systems.

Academic-capitalism research provides an institutional context for understanding such conversions [18]. The present framework identifies a more general mechanism in which epistemic throughput can become convertible into resources that later support further knowledge production.

The mechanism becomes especially important under automated and machine-assisted production because technical infrastructure can alter the relationship between human attention and total output volume. Section 8 develops this contemporary amplification in greater detail.

4.10 Coupled Feedback Structures

This subsection integrates the preceding mechanisms into a general feedback perspective. Its objective is to show how knowledge-capital expansion can emerge from coupled processes whose individual effects reinforce, constrain, or redirect one another across time.

A generative trajectory can involve several mechanisms simultaneously. Accumulated knowledge can improve question formation. Better questions can generate higher-value research outputs. Those outputs can produce reputation. Reputation can improve network access. Networks can provide new information and collaboration. Collaboration can generate additional knowledge and infrastructure. The resulting configuration can increase future capitalization capacity.

A general recursive system is represented in Equation 22.

$$(K_t, G_t, C_t, \Omega_t) \longrightarrow (K_{t+1}, G_{t+1}, C_{t+1}, \Omega_{t+1}). \quad (22)$$

Equation 22 represents the joint evolution of epistemic resources K_t , generative capacity G_t , a broader capital configuration C_t , and an inquiry possibility space Ω_t .

The representation remains deliberately abstract. Different empirical domains can require additional variables for institutions, infrastructure, labor relations, attention, legal rights, cultural conditions, technological systems, or other relevant structures. The purpose of Equation 22 is to make explicit that knowledge-capital expansion can involve co-evolution among several state variables.

Feedback can produce amplification when gains in one component increase later gains in another. It can produce stabilization when accumulated capacities reproduce a relatively persistent generative regime. It can also produce decline when attention, resources, institutional support, or complementary conditions become insufficient to sustain the cycle.

The dynamical perspective therefore resists treating knowledge-capital expansion as a uniform exponential process. Expansion can be intermittent, path-dependent, saturating, reversible in some dimensions, irreversible in others, and sensitive to institutional or technological changes.

These properties prepare the analysis of public knowledge developed in Section 5. Public availability introduces a shared external resource field into the dynamics described above. Actors enter that field with heterogeneous epistemic histories and capital configurations, creating the possibility that identical public resources generate substantially different recursive trajectories.

5 Public Knowledge and Capitalization Conditions

This section examines knowledge-capital expansion under conditions in which substantial epistemic resources are publicly accessible or broadly shared. Its role is to connect the dynamical mechanisms developed in Section 4 with the institutional and distributional problems created by a knowledge commons. The analysis proceeds through four stages. It first distinguishes public availability from effective epistemic accessibility and introduces public knowledge as a component of generative infrastructure. It then examines capitalization capacity and capitalization asymmetry under shared access. The section next develops the relations among openness, concentration, commons-to-private capitalization, circulation, and recirculation. It concludes by distinguishing enclosure of epistemic resources from enclosure of generative conditions and by identifying the transition from dynamical analysis toward the relations of epistemic production examined in Section 6.

5.1 Public Knowledge and Generative Infrastructure

This subsection defines the role of public knowledge within the present framework. Its objective is to move beyond a stock-based description of public information and to examine how shared epistemic resources can become productive conditions for future knowledge generation.

Knowledge-commons scholarship has established that knowledge can be examined as a shared resource whose creation, preservation, access, use, governance, and enclosure depend upon institutional arrangements [9]. Digital environments intensify the importance of this perspective because informational resources can often be reproduced and distributed across large populations at relatively low marginal cost.

The present framework emphasizes a further property of public knowledge: shared epistemic resources can become inputs into multiple subsequent generative processes. A publicly accessible article can contribute to many independent research trajectories. An open dataset can support questions that were absent from the project that originally created it. A public archive can be reinterpreted through later theoretical frameworks. Open software can become infrastructure for research projects across several disciplines.

Public knowledge can therefore function as *generative infrastructure*. The term refers to shared epistemic resources that contribute to the conditions under which later epistemic production becomes possible. The infrastructural function can arise through individual resources or through large interconnected environments of articles, datasets, repositories, libraries, standards, archives, software, educational materials, and public institutions.

This infrastructural perspective changes the unit of analysis. The relevant question concerns the future generative trajectories supported by a public resource field. A commons can therefore be evaluated partly through the possibilities of inquiry that it sustains across time.

The nonrival characteristics associated with many informational resources are important in this context. Arrow's analysis of information and invention emphasizes the distinctive economic properties of informational goods [1], while endogenous-growth theory later gives nonrival ideas a central role in technological development [17]. A shared epistemic resource can participate in several generative processes without being physically exhausted through each use.

The same property creates a distinctive political-economic problem. Wide availability can support broad generativity while leaving substantial differences in the capacity to convert shared resources into future productive advantage. Publicness therefore determines an important condition of access, while capitalization depends upon additional complementary conditions.

5.2 Public Availability and Effective Accessibility

This subsection distinguishes several layers of accessibility within a public knowledge environment. Its objective is to clarify why legal or technical availability provides an incomplete measure of the epistemic opportunities created by a commons.

A resource can be public in several senses. It can occupy the legal public domain, be released under an open license, be freely accessible through a public website, be available through a publicly funded institution, or circulate widely through social and scholarly networks. These arrangements differ in their legal status, governance, durability, and conditions of reuse.

Formal availability concerns whether an actor is permitted or technically able to obtain a resource. Effective accessibility concerns whether the actor can practically reach, interpret, process, and use that resource within a relevant epistemic trajectory.

The distinction is significant because several barriers can intervene between availability and use. A paper can be freely downloadable while remaining linguistically or technically inaccessible. A dataset can be public while requiring computational resources unavailable to many researchers. An archive can be open while demanding substantial travel, time, or specialist training. A model can be publicly documented while effective experimentation requires expensive hardware or proprietary complementary services.

Effective accessibility therefore depends upon a configuration of complementary resources. Public availability expands the potential input field, while the realized epistemic value of that field depends upon the capacity of actors to enter and operate within it.

This distinction also prevents openness from being represented through a single binary variable. Public knowledge systems can differ in discoverability, technical interoperability, linguistic accessibility, documentation, computational requirements, licensing conditions, preservation, and institutional stability. These dimensions can substantially alter the generative consequences of nominally open resources.

5.3 Capitalization Capacity under Shared Access

This subsection applies the concept of capitalization capacity to public knowledge. Its role is to explain how a shared resource field interacts with heterogeneous actor configurations and produces differentiated generative outcomes.

Let a public resource C be accessible to several actors. Each actor enters the capitalization process with a distinct configuration of prior epistemic resources, time, material support, institutional position, networks, languages, technical capabilities, and infrastructure. The generative consequence of C therefore depends upon the relation between the shared resource and the actor-specific configuration into which it enters.

Capitalization capacity can be represented conceptually through a function of several complementary conditions. A general representation is shown in Equation 23.

$$\kappa_i = \kappa(K_i, T_i, F_i, N_i, I_i, S_i, L_i, \dots), \quad (23)$$

where κ_i denotes the capitalization capacity of actor i , K_i prior epistemic resources, T_i available time, F_i financial resources, N_i network resources, I_i infrastructure, S_i institutional position, and L_i relevant linguistic or symbolic competence.

Equation 23 is a conceptual representation rather than an operational measurement model. Its purpose is to make explicit that capitalization capacity emerges from a configuration of conditions whose relative importance varies across epistemic domains.

The same public resource can therefore have different effective values across actors. A large open scientific dataset can be highly generative for an actor with appropriate methods, compute, and disciplinary knowledge. Its immediate generative value can be much smaller for an actor whose current conditions lack those complementary resources.

Public access thereby creates an opportunity field whose realized consequences depend upon distributed capitalization capacities.

5.4 Capitalization Asymmetry under Public Conditions

This subsection develops capitalization asymmetry specifically within public knowledge environments. Its objective is to identify the mechanism through which formally shared resources can generate divergent changes in future epistemic capacity.

Capitalization asymmetry arises when access to a common epistemic resource produces heterogeneous changes in generative capacity. The general relation introduced in Section 3 can be extended to a population of actors.

The population-level structure is represented in Equation 24.

$$\Delta G_i(C) = f(C, \kappa_i), \quad \kappa_i \neq \kappa_j \Rightarrow \Delta G_i(C) \neq \Delta G_j(C) \text{ in some regimes.} \quad (24)$$

Equation 24 represents the possibility that heterogeneous capitalization capacities generate heterogeneous changes in generativity from the same public resource.

The implication is probabilistic and conditional. Different capitalization capacities can sometimes produce similar outcomes, and actors with fewer material resources can generate highly original epis-

temic contributions. Capitalization asymmetry therefore identifies a structural possibility rather than a deterministic ranking of actors.

The mechanism becomes politically important when differences are recursively reproduced. An actor who extracts greater generative value from one public resource can acquire additional knowledge, reputation, infrastructure, or network access. These gains can increase the actor’s capacity to capitalize on subsequent public resources.

This recursive relation connects capitalization asymmetry with cumulative advantage. Merton’s analysis shows how scientific advantages can become self-reinforcing through recognition and institutional allocation [14]. The present framework extends the mechanism toward the productive conversion of shared epistemic resources themselves.

Capitalization asymmetry therefore concerns more than unequal outcomes from one round of public access. Its stronger form concerns unequal trajectories in which previous generative gains alter the conditions of later capitalization.

5.5 Openness and Concentration

This subsection develops the relationship between expansion of public accessibility and concentration of effective generative capacity. Its objective is to clarify how field-level openness and actor-level concentration can evolve simultaneously.

Increasing openness can enlarge the total quantity and diversity of epistemic resources available for use. Wider access can support replication, interdisciplinary transfer, education, independent inquiry, collective correction, and reuse across institutional boundaries. These effects can raise the generative capacity of the epistemic field as a whole.

The same increase in availability enters a field characterized by heterogeneous capitalization capacities. Actors possessing extensive complementary resources can sometimes absorb, process, and recombine newly available knowledge more rapidly than actors with weaker infrastructures or more constrained time, funding, or institutional access.

A possible joint trajectory is shown in Equation 25.

$$\Delta G_{\text{field}} > 0, \quad \Delta(G_A - G_B) > 0. \quad (25)$$

Equation 25 represents a regime in which total field-level generativity increases while the difference in generative capacity between actors A and B also increases.

The present paper refers to this possible configuration as an *openness–concentration paradox*. The term describes coexistence between broader epistemic accessibility and increasing concentration of effective capitalization capacity. It does not imply that openness itself is the sole or primary cause of concentration.

The mechanism can arise when openness removes an access barrier while leaving other complementary inequalities intact. Public release increases the resource field available to all actors, while differences in compute, attention, expertise, infrastructure, or institutional capacity continue to shape the rate of productive conversion.

The analytical implication is important for commons governance. Evaluation of openness can include both the aggregate expansion of public generativity and the distribution of capacities through which that generativity is realized.

5.6 Commons-to-Private Capitalization

This subsection examines trajectories in which publicly available epistemic resources contribute to privately or organizationally controlled increases in future generative capacity. Its objective is to distinguish productive use of a commons from the later governance of the capacities generated through that use.

Public knowledge can enter private epistemic accumulation without ceasing to remain publicly accessible. A researcher can learn from public literature and develop specialized expertise. A firm can

use public scientific findings to develop proprietary infrastructure. A platform can incorporate publicly produced informational resources into systems whose operation remains under private control.

A simplified trajectory is shown in Equation 26.

$$K_{\text{public}} \longrightarrow \mathcal{K}_A \longrightarrow G'_A \longrightarrow K'_A, \quad (26)$$

where K_{public} denotes a public epistemic resource field, $\mathcal{K}_A$ denotes actor A 's capitalization process, G'_A denotes enlarged generative capacity, and K'_A denotes resulting epistemic resources.

Equation 26 describes conversion and does not assign a normative status to the trajectory. Private capitalization can coexist with substantial public contribution, open publication, teaching, software release, collaborative infrastructure, or other forms of recirculation.

The political-economic question concerns what happens to the increased generative capacity after capitalization. The resulting capacity can remain widely accessible, become partially controlled, enter proprietary production, support public institutions, or move across several governance regimes.

Commons-to-private capitalization therefore identifies a transition point between public inputs and subsequent control structures. Section 6 later examines how ownership, control, labor, and appropriation shape the meaning of this transition.

5.7 Public Recirculation and Commons Regeneration

This subsection examines trajectories through which privately or institutionally accumulated epistemic capacity contributes to renewed public generative conditions. Its role is to establish recirculation as an analytical counterpart to commons-to-private capitalization.

An actor can capitalize upon public resources and later return epistemically productive outputs to the shared field. Such return can take the form of open publications, datasets, software, methods, educational materials, documentation, translations, standards, conceptual distinctions, archives, infrastructure, or other resources that enlarge subsequent possibilities for other actors.

A regenerative trajectory is represented in Equation 27.

$$K_{\text{public}} \longrightarrow G'_A \longrightarrow K'_A \longrightarrow K'_{\text{public}} \longrightarrow G'_{\text{field}}. \quad (27)$$

Equation 27 represents a cycle in which public resources contribute to actor-level generativity, resulting outputs return to the public field, and the enlarged commons supports subsequent field-level generation.

This trajectory illustrates a form of accumulation compatible with extensive public circulation. Individual or institutional knowledge capital can expand rapidly while outputs continue to regenerate shared epistemic conditions.

Generative justice provides a useful neighboring framework because it directs attention toward the circulation of value and the regeneration of the people and systems from which value emerges [5]. The present section uses recirculation descriptively. Questions concerning duties of return, fairness of circulation, and thresholds of extraction belong to the later Discussion and the dedicated ethical inquiry.

Recirculation also has several dimensions. An actor can return informational outputs while retaining exclusive infrastructure. A project can publish data while withholding methods required for practical reuse. A public result can depend upon proprietary tools whose cost restricts effective accessibility. The generative significance of return therefore depends upon which components of the productive configuration re-enter shared circulation.

5.8 Accumulation, Circulation, and Recirculation

This subsection differentiates accumulation from the movement of epistemic resources across actors and institutions. Its objective is to clarify how similar rates of knowledge-capital expansion can coexist with different patterns of circulation.

Accumulation concerns changes in the resources or generative capacity available to a particular actor or system. Circulation concerns movement of epistemic resources among actors, institutions, and public fields. Recirculation concerns the re-entry of resources generated through a capitalization process into a shared generative environment.

These processes can vary independently. High accumulation can coexist with high recirculation when rapidly expanding actors publish methods, concepts, data, or tools into shared environments. High accumulation can also coexist with limited circulation when outputs or infrastructures remain under restrictive control.

The distinction is essential for evaluating public knowledge systems. A field with high total production can exhibit limited circulation if outputs remain fragmented, inaccessible, or institutionally enclosed. A field with extensive formal circulation can exhibit weak practical recirculation if released resources lack documentation, interoperability, preservation, or complementary conditions required for future use.

Generative circulation therefore depends upon the capacity of epistemic outputs to enter subsequent productive cycles. Accessibility, interpretability, reusability, provenance, technical compatibility, and preservation can all affect this transition.

The analytical importance of recirculation lies in its effect on future capitalization possibilities. Resources returned to the commons can enlarge the input field available to subsequent actors, thereby modifying the generative conditions of the field itself.

5.9 Enclosure of Epistemic Resources

This subsection introduces enclosure at the level of epistemic resources. Its objective is to distinguish restrictions on access to existing knowledge from control over the wider conditions through which future knowledge is generated.

Knowledge-commons scholarship has examined enclosure through intellectual property, technological restrictions, contractual arrangements, access costs, and institutional practices that limit use of previously shared or potentially shareable resources [9]. Enclosure can therefore change the distribution of access even when the underlying informational resource remains technically reproducible.

Epistemic-resource enclosure concerns restrictions on the ability of actors to reach, reproduce, modify, analyze, or circulate specific epistemic resources. Examples can include paywalled publications, inaccessible datasets, contractually restricted archives, proprietary code, technical protection measures, or exclusive databases.

The generative consequence of such enclosure depends upon the resource's position within subsequent production. Restricting access to a highly complementary dataset can constrain an entire research pathway. Restricting a resource with many substitutes can have a smaller field-level effect.

Enclosure can also be partial. A publication can remain publicly readable while its underlying data are restricted. A model can be publicly accessible through an interface while its weights, training data, or deployment infrastructure remain controlled. Analytical treatment therefore requires specification of the resource layer at which enclosure occurs.

This resource-level conception prepares the distinction developed in the next subsection between enclosure of existing epistemic objects and enclosure of future generative capacity.

5.10 Enclosure of Generative Conditions

This subsection extends enclosure analysis from existing epistemic resources to the means and conditions required for future epistemic production. Its objective is to identify a form of control whose significance lies in governing future generative possibilities.

Generative conditions include infrastructure, compute, laboratories, archives, platforms, specialized instruments, data pipelines, publication systems, institutional credentials, funding mechanisms, model access, and other resources whose availability structures subsequent knowledge production.

Control over such conditions can shape future inquiry even when completed knowledge products remain publicly accessible. An actor can therefore exercise substantial influence over the production

of new knowledge through infrastructural control rather than through exclusive ownership of existing propositions.

A transition from resource access to generative control is represented in Equation 28.

$$K_{\text{public}} \longrightarrow I_A \longrightarrow G'_A \longrightarrow C'_A, \quad (28)$$

where I_A denotes infrastructure controlled by actor A , and C'_A denotes an enlarged set of controlled generative conditions.

Equation 28 represents a possible trajectory in which public epistemic inputs contribute to infrastructural capacity that subsequently increases control over future production.

This mechanism is particularly important for contemporary AI. Public literature, open-source software, public datasets, and collective scientific knowledge can contribute to privately controlled model infrastructures whose future generative capacity depends heavily upon compute, deployment systems, proprietary optimization, or platform access.

The resulting issue extends beyond ownership of individual knowledge products. Control can migrate toward the infrastructure through which future epistemic production becomes feasible. Section 8 develops this mechanism as a contemporary historical amplification.

5.11 Field-Level Generativity and Distribution

This subsection integrates the preceding analysis at the level of an epistemic field. Its objective is to distinguish total generative expansion from the distribution of generative capacity among actors and to prepare the transition toward political-economic relations.

A public knowledge environment can be evaluated along at least two dimensions. The first concerns field-level generativity: the total capacity of the field to produce new questions, knowledge, methods, data, and infrastructures. The second concerns the distribution of capitalization capacity and control over the conditions through which such generation occurs.

These dimensions can move in different directions. A new open repository can increase field-level generativity while actors with greater computational capacity derive disproportionately large gains. A proprietary platform can increase short-term aggregate output while concentrating infrastructural control. A public institution can produce substantial individual specialization while maintaining broad circulation of resulting resources.

Distributional analysis therefore requires more than measuring total knowledge production. The relevant questions concern who can capitalize upon shared resources, which actors control complementary conditions, how gains are converted across forms of capital, and whether resulting capacities return to the public field.

This distinction also clarifies the analytical status of the openness–concentration paradox. Openness concerns properties of the shared resource environment. Concentration concerns the distribution of effective generative capacity or control. Their coexistence becomes intelligible once field-level and actor-level variables are distinguished.

The public knowledge commons can consequently support several trajectories: broadly distributed generative expansion, asymmetric accumulation with continued public recirculation, concentrated accumulation accompanied by infrastructural control, or mixed configurations whose structure changes over time.

The dynamical analysis developed in Sections 4 and 5 identifies how these trajectories can emerge. Their political-economic interpretation requires a further shift from dynamics toward relations. Section 6 therefore examines control over means and conditions of epistemic production, the organization of epistemic labor, knowledge-capitalist and epistemic-proletarian positions, dependency, subordination, appropriation, precarity, and generative extraction.

6 Political Economy of Epistemic Production

This section develops the relational and institutional dimension of knowledge-capital expansion. Its role is to complement the dynamical analysis of Sections 4 and 5 by examining the organization of epistemic production around productive conditions, control, labor, appropriation, dependency, and circulation. The section first defines the means and conditions of epistemic production and distinguishes access from control. It then examines the organization of epistemic labor and separates capital-like expansion from capitalist relations. The subsequent subsections develop knowledge-capitalist and epistemic-proletarian positions, epistemic dependency, subordination, and generative precarity. The final part distinguishes accumulation from appropriation, clarifies ownership, possession, control, and appropriation, compares proprietary and socialized accumulation, and introduces generative extraction and generative exploitation as progressively stronger relational categories.

6.1 Generative Conditions and Means of Epistemic Production

This subsection defines the productive conditions through which epistemic generativity becomes practically realizable. Its objective is to establish a relational object comparable in analytical function to means of production in political economy while preserving the specific characteristics of knowledge production.

Epistemic generation depends upon more than the possession of propositions or information. Research can require time, education, language, archives, laboratories, software, computational resources, funding, institutional affiliation, communication channels, publication systems, collaborative networks, legal permissions, and access to previous knowledge. These elements form part of the conditions under which epistemic capacities can become productive.

The present framework uses *generative conditions* as the broadest category for such enabling conditions. Generative conditions include material, temporal, cognitive, relational, institutional, legal, and technological conditions that influence an actor's capacity to generate further epistemic resources.

Within this broader category, *means of epistemic production* refers to resources and infrastructures through which organized epistemic labor is conducted. Examples include laboratories, libraries, databases, instruments, computational systems, repositories, model infrastructures, publishing platforms, archives, and institutional research facilities.

The distinction is useful because some generative conditions remain embodied or relational rather than infrastructural. Linguistic competence, disciplinary training, trust within a research community, and uninterrupted time can be essential to generativity while functioning differently from laboratories or computational systems.

Marxian political economy provides the principal historical interlocutor for this relational analysis because control over means of production structures relations among productive actors [13]. The present framework carries the relational logic into epistemic production while preserving the differences between industrial production, scientific inquiry, learning, cultural production, and other epistemic practices.

The concept of means of epistemic production therefore identifies resources whose control can influence the practical organization of knowledge generation. Their political-economic significance depends upon how access, authority, labor, and resulting outputs are distributed across actors.

6.2 Control over Generative Conditions

This subsection distinguishes control from access and possession. Its objective is to identify the capacity to govern generative conditions as a central relational variable in epistemic production.

An actor can have access to a productive resource while possessing limited authority over its continued availability or permissible use. A researcher can use a laboratory without controlling its funding or admission policies. A scholar can access a database while the provider determines pricing, interfaces, technical restrictions, and future availability. A developer can use a model through an application programming interface while the model provider controls the underlying infrastructure.

Control therefore concerns practical capacity to determine conditions of use, availability, modification, allocation, exclusion, continuation, or circulation. Degrees of control can vary across resources and institutions.

Control over generative conditions can influence several dimensions of epistemic production. It can affect research agendas, permissible methods, access to data, pace of work, publication routes, infrastructure availability, resource allocation, and the capacity of other actors to participate in the same generative field.

Platform-capitalism scholarship illustrates the significance of infrastructural control in digitally mediated environments [20]. Academic-capitalism research similarly demonstrates how universities and associated organizations govern resources, intellectual property, research infrastructure, and market relations within knowledge production [18].

The political-economic significance of control therefore extends beyond legal ownership. An actor can exercise substantial practical control through contracts, technical architecture, administrative authority, funding, standards, or control over interfaces even where formal ownership is dispersed.

This distinction becomes central to the definition of knowledge-capitalist position developed below.

6.3 Epistemic Labor and the Organization of Knowledge Production

This subsection introduces epistemic labor as the productive activity through which epistemic resources are generated, interpreted, transformed, evaluated, maintained, or circulated. Its objective is to connect knowledge-capital dynamics with the division and organization of productive activity.

Epistemic labor includes activities such as observation, reading, interpretation, data collection, experimentation, classification, modeling, question formulation, conceptual analysis, translation, programming, verification, reviewing, editing, teaching, archival maintenance, and infrastructure development.

Different epistemic systems distribute these activities across individuals, teams, institutions, and technical systems. Contemporary research can involve principal investigators, research assistants, technicians, software engineers, data curators, editors, reviewers, librarians, administrators, and machine systems whose contributions occupy different positions within the productive process.

The organization of epistemic labor influences who determines research questions, who performs specific productive tasks, who receives recognition, who controls infrastructure, who owns or governs outputs, and who can convert the resulting resources into future generative advantage.

The analytical distinction between epistemic labor and control over productive conditions is therefore essential. An actor can contribute substantial direct epistemic labor while exercising limited authority over the infrastructure, agenda, circulation, or resulting capital. Another actor can exercise considerable organizational control while performing a smaller share of the underlying epistemic labor.

These relations become increasingly important when knowledge production is distributed across large institutions or computational infrastructures. AI systems further complicate the organization of epistemic labor by allowing some activities to be automated, parallelized, or delegated to machine systems. Section 8 examines this transformation in greater detail.

6.4 Capital-Like Expansion and Capitalist Relations

This subsection formalizes the distinction between capital-like expansion and capitalist relations. Its role is to prevent dynamical properties of knowledge accumulation from being conflated with social positions within the organization of epistemic production.

Knowledge-capital expansion concerns trajectories through which epistemic resources modify future generative capacity. A trajectory can display recursive accumulation, second-order generativity, cross-domain recombination, cross-capital conversion, or increasing capitalization capacity.

Capitalist relations concern the organization of control, labor, appropriation, and productive conditions among actors. The relevant questions therefore concern who controls major means of epistemic production, who depends upon those conditions, who performs epistemic labor, and how resulting resources and capacities are allocated.

The distinction established in Subsection 3.13 can consequently be stated through two analytical axes: expansion dynamics and relational position.

A researcher who rapidly accumulates knowledge through public learning can display strong knowledge-capital expansion while retaining limited control over other producers. A cooperative research community can exhibit extensive recursive accumulation while maintaining distributed control. A corporation can control extensive epistemic infrastructure while particular owners or executives perform limited direct knowledge production.

Capital-like expansion therefore specifies a property of a trajectory. Capitalist position specifies a location within relations of production. Their interaction is an empirical and institutional question.

This distinction also clarifies why accumulation by itself supplies limited information about appropriation. Accumulated generative capacity can be circulated broadly, maintained within a commons, concentrated institutionally, or converted into exclusive control. The relational structure governing the accumulation determines its political-economic character.

6.5 Knowledge-Capitalist Position

This subsection develops the concept of *knowledge capitalist* as a relational category. Its objective is to identify a position characterized by substantial control over the means and conditions of epistemic production and the capacity to organize, scale, or appropriate epistemic production.

A knowledge capitalist is provisionally defined as an actor occupying a relational position characterized by substantial control over significant means or conditions of epistemic production, enabling the actor to organize, direct, scale, and appropriate epistemic production beyond the actor's own direct epistemic labor.

The category can apply to individuals, organizations, firms, platforms, or other institutional actors. Its analytical basis lies in relational control rather than quantity of personally embodied knowledge.

Several characteristics can indicate such a position. An actor can control infrastructure required by other knowledge producers, allocate resources across research activities, determine conditions of access, organize large-scale epistemic labor, appropriate resulting outputs or advantages, and convert these returns into further control over productive conditions.

The concept therefore extends the distinction between capitalist and capital reviewed in Subsection 2.3. Marx's treatment of the capitalist as the social bearer of capital provides a conceptual precedent for distinguishing the dynamics of expansion from the actor occupying a structurally privileged productive position [13].

The knowledge-capitalist category remains broader than ownership of intellectual property. Intellectual property can contribute to control, while infrastructural authority, funding power, administrative governance, platform control, and technical architecture can also produce knowledge-capitalist positions.

The category is therefore relational and scalar. An actor can occupy a knowledge-capitalist position within one productive configuration while remaining dependent upon another actor at a larger infrastructural scale.

6.6 Epistemic-Proletarian Position

This subsection develops *epistemic proletariat* as the relational counterpart to the knowledge-capitalist category. Its objective is to describe knowledge producers possessing generative capacity while lacking stable control over principal conditions required to realize and reproduce that capacity.

An epistemic-proletarian position is provisionally characterized by the presence of epistemic generative capacity together with substantial dependence upon generative conditions governed by other actors or institutions.

The core relation is expressed in Equation 29.

$$G_S > 0, \quad C_G \notin \text{control}(S), \quad (29)$$

where G_S denotes the generative capacity of subject S , and C_G denotes generative conditions required for continued epistemic production.

Equation 29 represents a structural condition rather than a complete class theory. The subject possesses productive capacity while principal enabling conditions remain under external control.

Examples can include researchers dependent upon temporary institutional appointments, independent scholars requiring proprietary databases, workers producing data or annotations within externally governed infrastructures, or researchers whose continued generativity depends upon access to laboratories, compute, or funding controlled elsewhere.

The category therefore concerns relations between generative capacity and control. It does not imply low education, limited expertise, low status, or low epistemic output. Highly skilled knowledge producers can occupy structurally dependent positions.

The provisional category also admits degrees and mixed configurations. A researcher can control some generative conditions while depending heavily upon others. Epistemic-proletarian position therefore functions as an analytical ideal type whose boundaries require later empirical investigation.

6.7 Epistemic Dependency

This subsection defines epistemic dependency as a relation in which continued knowledge generation depends substantially upon generative conditions governed by another actor. Its role is to distinguish dependency from stronger forms of subordination.

Epistemic dependency arises when loss of access to a resource, infrastructure, institution, or relation controlled elsewhere would materially reduce an actor's capacity to continue a relevant epistemic trajectory.

Dependency can concern laboratories, employment, compute, databases, software, archives, funding, publication systems, institutional affiliation, model access, or collaborative networks. Its intensity depends upon the importance of the resource, availability of substitutes, switching costs, and the actor's capacity to reconstruct the required condition independently.

Dependency can be reciprocal. Collaborating researchers can depend upon one another's expertise. Institutions can depend upon highly specialized workers. Open-source communities can depend upon maintainers while maintainers depend upon distributed contributions. Reciprocal dependency can support cooperative generativity when control remains sufficiently balanced.

Political-economic significance increases when dependency is asymmetric. An actor controlling a difficult-to-substitute generative condition can acquire greater capacity to influence the dependent actor's productive trajectory.

This transition motivates the concept of epistemic subordination developed in the following subsection.

6.8 Epistemic Subordination

This subsection develops epistemic subordination as a stronger relational condition emerging from asymmetric dependency. Its objective is to identify situations in which control over generative conditions provides one actor with material capacity to govern another actor's epistemic production.

Epistemic subordination occurs when dependency permits another actor to influence significant dimensions of the dependent producer's research agenda, pace, access, recognition, circulation, methods, or future opportunities.

The relevant power can be exercised through explicit commands or through structural conditions. Funding criteria can influence research direction. Access rules can determine which projects are feasible. Employment structures can condition publication or intellectual-property arrangements. Platform design can influence visibility and circulation. Model providers can determine which capabilities remain available to downstream users.

Subordination therefore concerns governance of productive possibilities. Its presence depends upon the combination of dependency, control, and the capacity to shape another actor's generative trajectory.

The concept remains distinct from ordinary coordination. Collaborative research requires division of roles, deadlines, standards, and shared decision-making. Subordination concerns an asymmetric capacity to govern another actor's productive conditions without equivalent reciprocal control.

This distinction is important for later normative analysis because dependency and coordination can support highly generative relations, while persistent asymmetric governance can constrain epistemic agency and future generativity.

6.9 Generative Precarity

This subsection introduces generative precarity as instability in the conditions required for sustained epistemic production. Its objective is to capture a temporal dimension of dependence that cannot be represented solely through current resource access.

Generative precarity exists when an actor's access to important material, temporal, relational, cognitive, institutional, or technological conditions remains unstable enough to threaten continuity of epistemic generation.

Temporary employment provides one possible mechanism. A researcher can possess extensive expertise and current institutional access while facing an imminent loss of salary, affiliation, laboratory resources, visas, databases, or research infrastructure. The actor's present generativity can therefore coexist with uncertainty concerning future productive continuity.

Precarity can also arise through volatile platform access, changing licensing conditions, unstable funding, reliance on discontinued software, fragile collaborative networks, or concentration of essential services in a small number of providers.

The concept is especially relevant to knowledge-capital expansion because recursive processes depend upon continuity. Interruptions can prevent previous accumulation from being converted into later generative capacity. An actor can possess substantial epistemic capital while lacking stable conditions for its continued capitalization.

Generative precarity therefore adds temporal stability to the political economy of knowledge production. The distribution of future security can matter as much as the distribution of present resources.

6.10 Accumulation and Appropriation

This subsection distinguishes accumulation from appropriation. Its objective is to separate growth in generative resources from incorporation of generated or shared value into an actor's controllable accumulation cycle.

Accumulation occurs when an actor or system increases epistemic resources or future generative capacity. Appropriation concerns the relational trajectory through which value originating in shared, collective, or externally produced resources becomes incorporated into an actor's sphere of control.

The distinction is essential under public knowledge. Learning from public resources produces personal accumulation. Such accumulation can occur through ordinary participation in a commons and can contribute subsequently to further public circulation.

Appropriation becomes analytically relevant when attention shifts to the control and disposition of resulting value. An actor can incorporate publicly generated resources into proprietary infrastructure, exclusive institutional advantage, reputational capital, or other controlled productive conditions.

Accumulation and appropriation can therefore overlap while retaining different objects. Accumulation concerns what grows. Appropriation concerns how generated or shared value enters relations of control.

This distinction also prevents rapid individual learning from being treated as equivalent to extractive accumulation. A scholar can accumulate extensive knowledge through public resources while contributing new work back to the commons. The political-economic analysis requires tracing circulation, control, and effects on future generative conditions.

6.11 Ownership, Possession, Control, and Appropriation

This subsection differentiates four relations that frequently become conflated in discussions of knowledge and intellectual property. Its role is to provide the conceptual basis required for the later jurisprudential Discussion.

Ownership refers to a legally recognized structure of rights concerning an object or resource. The content of ownership varies across legal regimes and resource types.

Possession refers to factual holding, access, or availability. A person can possess a copy of a work or know a concept without possessing legal ownership of the underlying rights.

Control refers to practical capacity to govern access, use, modification, allocation, circulation, or continuation. Control can arise through legal rights, technical infrastructure, contracts, institutional authority, or other arrangements.

Appropriation refers to incorporation of generated or shared value into an actor's own controllable accumulation process.

These categories can therefore diverge. An actor can own a resource while delegating practical control. A platform can exercise substantial control over resources that it does not legally own. A public epistemic resource can be widely possessed while the infrastructure required for effective use remains concentrated.

The distinction is particularly important for knowledge because informational resources can be reproduced across many holders. Political-economic power can therefore arise through control over generative conditions even when possession of completed knowledge remains broadly distributed.

Section 9 later returns to these distinctions when examining priority, provenance, stewardship, ownership, licensing, and enclosure.

6.12 Proprietary and Socialized Accumulation

This subsection compares two idealized trajectories for governing accumulated epistemic capacity. Its objective is to show that rapid knowledge-capital expansion can occur within different circulation and control structures.

Proprietary accumulation refers to trajectories in which increases in generative capacity become progressively incorporated into exclusive or restricted structures of control. Resulting advantages can include proprietary data, infrastructure, intellectual property, closed methods, restricted model access, or organizational capacities unavailable to other actors.

Socialized accumulation refers to trajectories in which substantial accumulation occurs while resulting epistemic resources continue to enter shared generative conditions. Open publication, reusable methods, public datasets, educational transmission, commons infrastructure, and collaborative governance can contribute to such trajectories.

The distinction concerns governance of accumulated capacity. Both trajectories can involve high levels of innovation, expertise, and recursive expansion. Their relational structures differ in the circulation and control of resulting generative resources.

Mixed configurations are common. A research organization can publish findings openly while retaining proprietary infrastructure. A scholar can release articles while maintaining private notes or datasets. A firm can open-source software while monetizing complementary services.

The ideal types therefore support comparative analysis rather than exhaustive classification. Their value lies in separating the magnitude of accumulation from the institutional form through which accumulated capacity is governed.

6.13 Generative Extraction

This subsection introduces generative extraction as a relational pattern in which an actor draws generative resources from another subject or shared field while disproportionately retaining the resulting increase in

generative capacity. Its objective is to identify a stronger category than asymmetric capitalization while preserving a distinction from generative exploitation.

The concept draws upon generative justice, particularly its attention to circulation of value and regeneration of source communities and systems [5]. Applied to epistemic production, the relevant question concerns how value derived from public or collective generative resources circulates after capitalization.

A simplified extractive trajectory is shown in Equation 30.

$$C_{\text{source}} \longrightarrow G'_A \longrightarrow K'_A, \quad K'_A \not\rightarrow C'_{\text{source}}, \quad (30)$$

where C_{source} denotes generative resources provided by a source field and K'_A denotes the resulting increase in actor A 's epistemic capital.

Equation 30 represents a one-directional circulation pattern in which the source contributes to enlarged private generative capacity while receiving limited regenerative return.

The analytical category requires more than unequal benefit. An actor can gain more than others from public knowledge without extracting from the commons in a meaningful relational sense. Generative extraction becomes relevant when there is a systematic flow from a source field into an actor's accumulation cycle accompanied by substantial asymmetry in retention and regeneration.

The concept is therefore especially useful for recursive cases. Extracted public value can become new capital that increases the actor's capacity to capitalize upon the next round of public resources. Extraction can then contribute to self-reinforcing asymmetry.

The normative significance of such a pattern depends upon additional criteria. The next subsection introduces generative exploitation as a stronger category requiring further effects on the source's generative conditions.

6.14 Preliminary Boundaries of Generative Exploitation

This subsection establishes preliminary boundaries for the concept of generative exploitation. Its objective is to prevent the term from becoming a general label for every asymmetric or privately beneficial use of shared epistemic resources.

Generative exploitation is provisionally reserved for stronger relational configurations in which generative extraction is accompanied by material degradation, suppression, dependency, lock-in, or erosion of the source's future generative conditions.

The distinction creates a conceptual sequence from capitalization asymmetry to extraction and from extraction to exploitation. Each transition requires additional relational conditions.

Capitalization asymmetry concerns unequal generative gains. Generative extraction concerns systematic one-directional appropriation accompanied by insufficient regeneration of the source. Generative exploitation concerns extractive relations that additionally impair, constrain, or subordinate the future generativity of the source or participating producers.

This sequence avoids treating every instance of public-resource use as normatively equivalent. A researcher who learns from public literature and publishes further open work occupies a different relational configuration from an actor who converts collective epistemic resources into exclusive infrastructure while reducing the capacity of contributors to continue participating.

The threshold between extraction and exploitation remains an open normative problem. Evaluation can require attention to consent, dependency, control, distribution of resulting capacities, alternatives available to participants, recirculation, regeneration, and long-term effects on the generative field.

The present paper therefore introduces generative exploitation as a provisional analytical frontier. Section 9 considers its ethical implications, while a dedicated normative inquiry is required to establish criteria capable of supporting stronger evaluative claims.

The relational categories developed in this section complete the transition from knowledge-capital dynamics to a political economy of epistemic production. Knowledge-capital expansion describes changes in generative trajectories. Means of epistemic production, control, labor, dependency, appropriation, and

class-like positions describe the relational organization within which those trajectories unfold. Section 7 integrates these dimensions into a preliminary analytical framework.

7 A Preliminary Analytical Framework

This section consolidates the conceptual, dynamical, commons-oriented, and political-economic analyses developed in Sections 3–6 into a preliminary analytical framework. Its role is to specify the principal units, variables, relations, and trajectories required for comparative analysis of knowledge-capital expansion. The section proceeds from units and levels of analysis to actor-resource-condition configurations, epistemic-capital states, capitalization functions, recursive dynamics, heterogeneous trajectories, institutional constraints, cross-capital feedback, public and private capitalization pathways, concentration processes, and recirculation. The framework remains intentionally general. Its purpose is to organize later empirical and formal work without imposing a single metric across heterogeneous epistemic domains.

7.1 Analytical Units and Levels

This subsection specifies the units and levels through which knowledge-capital expansion can be analyzed. Its objective is to avoid reducing the framework to either individual cognition or institutional political economy and to preserve the possibility of relations across multiple scales.

The basic analytical unit is a generative configuration involving an actor, one or more epistemic resources, and the conditions through which those resources become generatively operative. An actor can be an individual, collective, organization, institution, platform, or other system capable of participating in epistemic production.

Four principal levels are provisionally distinguished.

The *individual level* concerns embodied knowledge, questions, methods, skills, interpretive capacities, attention, time, and personally accessible tools.

The *collective level* concerns research groups, communities, networks, collaborations, and other configurations in which epistemic resources and generative capacities are distributed across several actors.

The *institutional level* concerns organizations that allocate resources, govern infrastructure, organize epistemic labor, define access conditions, and mediate recognition or circulation.

The *field level* concerns wider epistemic environments composed of public knowledge, infrastructures, legal arrangements, institutions, disciplines, markets, platforms, and other structures within which multiple actors interact.

These levels are analytically distinguishable while remaining coupled. Individual generativity can depend upon institutional infrastructure. Institutional capacities can depend upon collective epistemic labor. Field-level public knowledge can enter individual capitalization processes. Individual outputs can subsequently alter the shared epistemic field.

The framework therefore treats scale as part of the analytical specification. A statement concerning knowledge-capital expansion should identify the actor or system whose resources and generative capacity are being examined and the larger conditions within which that trajectory occurs.

7.2 Actors, Epistemic Resources, and Generative Conditions

This subsection defines the elementary configuration from which the framework is constructed. Its objective is to represent knowledge-capital expansion through relations among actors, epistemic resources, and generative conditions.

Let A_i denote actor i , $K_i(t)$ the epistemic resources available to that actor at time t , and $C_i(t)$ the wider configuration of generative conditions affecting the actor's epistemic activity. The resulting analytical state is shown in Equation 31.

$$X_i(t) = (A_i, K_i(t), C_i(t)). \quad (31)$$

Equation 31 represents the actor together with the epistemic resources and generative conditions relevant to a specified domain of inquiry.

The separation between $K_i(t)$ and $C_i(t)$ is functional rather than ontological. A resource can occupy either category depending upon the analytical problem. A software package can be treated as an epistemic resource when examining how it contributes to one research task and as part of infrastructure when examining dependence upon externally controlled computing systems.

The generative condition set can include time, funding, language, institutional access, networks, legal permissions, computational resources, laboratories, platforms, publication systems, and other relevant conditions. The composition of $C_i(t)$ should therefore be specified according to the empirical domain.

The same public epistemic resource can enter several actor configurations simultaneously. Its effects then depend upon the complementary epistemic and generative conditions associated with each actor.

7.3 Epistemic-Capital States

This subsection introduces a state representation for knowledge capital. Its role is to distinguish the quantity of available epistemic resources from their composition, connectivity, accessibility, and generative relevance.

A knowledge-capital state cannot generally be represented adequately through a single scalar quantity. Two actors can possess similar amounts of information while differing substantially in conceptual organization, methodological capacity, cross-domain connectivity, question repertoire, or access to complementary infrastructure.

The framework therefore treats the epistemic-capital state $K_i(t)$ as a structured configuration. A provisional decomposition is shown in Equation 32.

$$K_i(t) = (P_i, Q_i, C_i^{\text{con}}, M_i, D_i, T_i, R_i^{\text{epi}}, \dots)_t, \quad (32)$$

where P_i denotes propositions or established knowledge, Q_i questions, C_i^{con} concepts and distinctions, M_i methods, D_i data or archives, T_i tools or techniques, and R_i^{epi} relational epistemic resources.

Equation 32 provides a categorical representation rather than an additive measure. The components can differ in form, scale, and observability.

Connectivity among components is also relevant. A method becomes more generative when connected to suitable problems. A dataset becomes more useful when an actor possesses concepts and techniques required for interpretation. A question can become highly productive when it connects previously separate resource clusters.

The state of knowledge capital therefore includes both resources and relations among resources. Later empirical applications can represent these relations through network, graph, semantic, historical, or other domain-specific structures.

7.4 Capitalization Functions

This subsection formalizes epistemic capitalization as a transformation from accessible resources and generative conditions into changes in future generative capacity. Its objective is to provide a common analytical structure for comparing heterogeneous capitalization processes.

Let $E_i(t)$ denote an epistemic resource encountered or accessed by actor i , and let $\kappa_i(t)$ denote the actor's capitalization capacity. A general capitalization relation is shown in Equation 33.

$$\Delta G_i(t+1) = \Phi(E_i(t), K_i(t), C_i(t), \kappa_i(t)), \quad (33)$$

where Φ denotes a domain-dependent capitalization function.

Equation 33 states that the generative effect of an epistemic input depends upon the input, the actor's prior epistemic configuration, wider generative conditions, and capitalization capacity.

The function Φ need not be linear. Complementarity can produce super-additive effects, redundancy can produce diminishing effects, and missing conditions can prevent an accessible resource from becoming generatively operative.

Capitalization capacity can itself depend upon the current configuration of resources and conditions. The concept is therefore endogenous to the recursive system. Successful capitalization can alter future κ_i through learning, infrastructure, reputation, networks, or institutional access.

This structure allows empirical work to investigate different capitalization mechanisms without requiring a universal functional form.

7.5 Recursive Expansion Processes

This subsection combines epistemic states and capitalization functions into a recursive temporal process. Its role is to specify how outputs from one stage can modify the conditions of subsequent epistemic production.

A general recursive update is shown in Equation 34.

$$(K_i(t+1), G_i(t+1), C_i(t+1)) = \Psi(K_i(t), G_i(t), C_i(t), E_i(t)), \quad (34)$$

where Ψ denotes the combined transformation through which epistemic resources, generative capacity, and generative conditions evolve.

Equation 34 permits several mechanisms to operate within the same trajectory. New knowledge can enlarge conceptual capacity. Successful output can generate reputation. Reputation can improve network access. Network access can produce new epistemic inputs. Financial returns can support infrastructure. Infrastructure can increase future throughput or experimental capability.

Recursive expansion therefore concerns changes in the state-transition structure itself. A successful cycle can alter the resources and conditions through which the next cycle is generated.

The trajectory can display acceleration, saturation, interruption, reorientation, or decline. Empirical analysis should therefore examine the shape of the trajectory and the mechanisms producing changes across time.

7.6 Heterogeneous Capitalization Trajectories

This subsection develops actor heterogeneity within the analytical framework. Its objective is to represent divergent knowledge-capital trajectories arising from differences in initial conditions, capitalization capacities, and generative environments.

Consider two actors exposed to a common public epistemic resource field. Different prior states can lead to different subsequent trajectories even when the accessible external input is similar.

The divergence can be represented conceptually through Equation 35.

$$X_A(t_0) \neq X_B(t_0) \implies X_A(t_n) \neq X_B(t_n) \text{ under some recursive regimes.} \quad (35)$$

Equation 35 describes path-dependent divergence under specified recursive conditions. It does not imply that different initial states necessarily produce increasing inequality.

Several trajectory forms are possible. Initial differences can widen, remain stable, narrow, reverse, or become irrelevant after structural changes. Educational access, public infrastructure, technological change, institutional support, collaboration, or changes in research direction can alter the relative importance of previous advantages.

The analytical task is therefore to identify the mechanisms through which heterogeneity persists or changes. Capitalization asymmetry becomes especially important when previous gains modify the capacity to benefit from subsequent shared resources.

7.7 Relational and Institutional Constraints

This subsection integrates the relational categories developed in Section 6 into the analytical framework. Its objective is to represent how control, dependency, institutional rules, and infrastructural arrangements shape the feasible trajectories of knowledge-capital expansion.

Generative conditions are governed through institutional arrangements. Funding systems allocate resources. Universities control laboratories and affiliations. Publishers govern circulation channels. Platforms govern interfaces and technical access. Legal systems structure ownership, permissions, and remedies. Research communities establish standards of recognition and credibility.

These structures can be represented through a constraint set $\mathcal{R}_i(t)$ associated with actor i . The feasible generative trajectory then depends upon the interaction among epistemic resources, capitalization capacity, and relational constraints.

A general constrained transition is shown in Equation 36.

$$X_i(t+1) = \Psi(X_i(t), E_i(t) \mid \mathcal{R}_i(t)). \quad (36)$$

Equation 36 indicates that the transition from one epistemic state to another occurs within a relational and institutional environment.

The constraint set can include enabling as well as limiting structures. Institutional standards can improve reliability. Shared infrastructure can reduce individual costs. Stable funding can preserve long-term inquiry. Collaborative governance can expand access to specialized resources.

The framework therefore treats institutions as constitutive components of epistemic production rather than external background variables.

7.8 Cross-Capital Feedback

This subsection integrates epistemic capital with reputational, financial, network, institutional, and infrastructural resources. Its objective is to represent feedback among heterogeneous forms of accumulated capacity without collapsing them into a common metric.

Let the broader capital configuration of actor i be represented by Equation 37.

$$\mathbf{C}_i(t) = (K_i, R_i, F_i, N_i, S_i, I_i, \dots)_t. \quad (37)$$

Equation 37 distinguishes epistemic capital K_i , reputation R_i , financial resources F_i , network resources N_i , institutional or status resources S_i , and infrastructure I_i .

Conversion can occur in several directions. Epistemic output can produce reputation, reputation can facilitate funding, funding can support infrastructure, and infrastructure can increase future epistemic capacity. Institutional position can provide access to networks or archives, while networks can generate new research opportunities.

The analytical importance lies in recursive coupling. A relatively small epistemic advantage can become amplified when it is repeatedly converted into resources that return to the epistemic process.

Conversion also depends upon institutional arrangements. The same scholarly output can generate different reputational or financial consequences across fields. Infrastructure can produce substantial epistemic returns in compute-intensive research and limited returns in other forms of inquiry.

Cross-capital analysis therefore requires attention to conversion pathways and their institutional conditions.

7.9 Public and Private Capitalization Pathways

This subsection organizes capitalization trajectories according to the relation between public epistemic inputs and the governance of resulting generative capacities. Its objective is to provide a comparative framework for different circulation and control structures.

A public epistemic resource can enter several trajectories.

In a *public-to-public pathway*, shared resources support generation whose resulting epistemic outputs substantially re-enter public circulation.

In a *public-to-private pathway*, public resources contribute to generative capacities or outputs whose subsequent control becomes concentrated within an individual or organization.

In a *private-to-public pathway*, privately generated or controlled resources are released into a wider commons and become generative inputs for other actors.

In a *mixed pathway*, different components of the productive system operate under different governance regimes. Publications can be open while datasets remain restricted, or open software can depend upon proprietary infrastructure.

These pathways concern circulation and control rather than moral evaluation. The same institutional arrangement can contain several pathways simultaneously.

The framework therefore recommends tracing specific resource flows instead of classifying entire actors or institutions through a single public/private binary.

7.10 Accumulation and Concentration Trajectories

This subsection distinguishes expansion of epistemic capacity from changes in its distribution across a field. Its objective is to provide a preliminary framework for analyzing concentration without conflating it with individual accumulation.

Let $G_i(t)$ denote the generative capacity of actor i . Field-level expansion concerns changes in the aggregate or distributed generative capabilities of the field. Concentration concerns the degree to which effective generative capacity, infrastructure, or control becomes increasingly located within a smaller subset of actors.

Accumulation and concentration can therefore follow different trajectories. Many actors can experience simultaneous expansion with relatively stable distribution. Field-level generativity can increase while concentration also increases. Redistribution of infrastructure can reduce concentration even while total epistemic output continues to grow.

The Marxian distinction between concentration and centralization reviewed in Subsection 2.4 remains useful here. Expansion through internal accumulation differs from expansion produced through acquisition, merger, aggregation, or consolidation of previously distributed epistemic resources or infrastructures.

In knowledge systems, centralization can concern databases, publishing platforms, research institutions, computational infrastructure, model providers, archives, or other generative conditions. Its analysis therefore requires both resource-distribution and control variables.

The openness–concentration problem identified in Subsection 5.5 can be analyzed within this framework by comparing changes in public accessibility, field-level generativity, and distribution of capitalization capacity over time.

7.11 Circulation and Recirculation Pathways

This subsection integrates circulation into the analytical framework. Its objective is to represent how epistemic resources generated through one capitalization cycle re-enter, bypass, or become restricted from subsequent shared generative environments.

Let K'_i denote epistemic resources produced by actor i , and let ρ_i represent the proportion or structure of those resources that becomes practically available for subsequent public or collective generation. A schematic recirculation relation is shown in Equation 38.

$$K'_i \xrightarrow{\rho_i} K'_{\text{commons}} \longrightarrow G'_{\text{field}}. \quad (38)$$

Equation 38 represents the movement of actor-level epistemic output into an enlarged commons and its potential contribution to field-level generativity.

The parameter ρ_i should not be interpreted as a simple publication ratio. Effective recirculation depends upon accessibility, documentation, interoperability, legal permissions, discoverability, preservation, interpretability, and complementary infrastructure.

A formally public resource can therefore exhibit weak generative recirculation. Conversely, a relatively small contribution can have substantial field-level consequences when it provides a highly reusable method, dataset, question, standard, or conceptual distinction.

Recirculation can also concern generative conditions. An actor can contribute training resources, open infrastructure, funding, translation, standards, or institutional support that enlarges the capitalization capacities of other actors.

This broader interpretation prepares the later discussion of generative return and commons regeneration.

7.12 Analytical Boundaries and Model Limitations

This subsection specifies the boundaries of the preliminary framework. Its role is to identify assumptions requiring later theoretical refinement and to prevent the formal vocabulary from creating a false impression of measurement precision.

The first limitation concerns heterogeneity. Knowledge capital includes resources with different ontological, temporal, and functional properties. Questions, embodied competence, datasets, social relations, and infrastructure cannot generally be reduced to a common unit without substantial loss of information.

The second limitation concerns observability. Generative capacity is partly latent. A concept acquired today can become productive only after a later encounter with another problem. Immediate output therefore provides an incomplete measure of accumulated epistemic capital.

The third limitation concerns counterfactual identification. Establishing that a resource caused an increase in later generativity requires comparison with a trajectory in which the resource was absent or differently configured. Such counterfactuals are difficult to establish in historical and individual epistemic development.

The fourth limitation concerns scale. Individual, collective, institutional, and field-level capital can interact without being directly aggregable. An institution can possess strong infrastructure while individual members experience high generative precarity. Field-level expansion can coexist with actor-level decline.

The fifth limitation concerns relational endogeneity. Control, recognition, funding, and access can change in response to previous epistemic outcomes. Generative conditions therefore evolve together with epistemic states.

The sixth limitation concerns normative neutrality. The framework identifies accumulation, capitalization, concentration, circulation, dependency, and extraction as analytical relations. Their ethical and jurisprudential evaluation requires additional criteria concerning justice, rights, responsibility, consent, stewardship, and effects on future generativity.

The seventh limitation concerns the boundary of capital terminology. Recursive generativity alone may provide insufficient reason to classify every epistemically productive resource as capital. Historical comparison, conceptual analysis, and empirical application are required to determine where the analogy remains explanatory and where alternative vocabulary provides greater precision.

The preliminary analytical framework should therefore be understood as an organizing architecture rather than a completed quantitative model. Its principal function is to specify which relations should be distinguished when examining knowledge-capital expansion: epistemic resources, generative capacity, capitalization capacity, public inputs, complementary conditions, cross-capital conversions, institutional constraints, relational positions, circulation, and control.

Section 8 applies this architecture to artificial intelligence as a contemporary amplification of epistemic absorption, capitalization, throughput, and infrastructural control. The application also provides a concrete setting in which several otherwise abstract mechanisms become especially visible.

8 Artificial Intelligence and Contemporary Knowledge-Capital Expansion

This section applies the analytical framework developed in Sections 3–7 to artificial intelligence as a contemporary transformation in the means and conditions of epistemic production. Its role is illustrative and diagnostic. The objective is to examine how AI can alter epistemic absorption, capitalization capacity, throughput, question-space exploration, capital intensity, and control over generative infrastructure while preserving knowledge-capital expansion as the broader theoretical object of the paper. The discussion proceeds from AI-mediated access to epistemic resources toward machine-scaled production and industrialized capitalization, and then examines the distribution and governance of the resulting generative capacities. The analysis uses AI in science as a principal empirical reference point because recent assessments document applications across multiple domains and stages of research together with significant implications for productivity, infrastructure, skills, and governance [15].

8.1 AI-Mediated Epistemic Absorption

This subsection introduces *epistemic absorption capacity* as the first mechanism through which AI can alter knowledge-capital expansion. Its objective is to distinguish the legal or technical availability of public knowledge from the amount of that knowledge that an actor can practically locate, process, compare, and incorporate into an active epistemic trajectory. The discussion focuses on changes in search, retrieval, translation, summarization, classification, and cross-document synthesis.

The contemporary knowledge commons contains quantities of literature, data, code, archives, and other epistemic resources that substantially exceed the attention available to any individual researcher. Public accessibility therefore leaves a gap between the epistemic resources that can in principle be reached and the resources that can practically enter a research process.

AI can alter this relation by lowering some of the temporal and cognitive costs associated with locating and processing external knowledge. Search and retrieval systems can identify relevant materials across large corpora. Language technologies can support translation and terminology mapping. Machine-assisted summarization and classification can reduce the effort required for preliminary screening. Literature-based discovery systems can identify possible relations among dispersed findings. The OECD review of AI in science discusses these capacities in connection with knowledge discovery, scientific productivity, and machine-assisted organization of research knowledge [15].

The present framework describes the resulting capability as *epistemic absorption capacity*: the amount, diversity, and structural complexity of external epistemic resources that an actor or system can practically bring into a generative process within a specified period and resource environment.

Epistemic absorption involves more than retrieval volume. A system that retrieves thousands of documents without effective relevance assessment can increase informational exposure while producing limited generative gain. Absorption therefore includes selection, interpretation, relation formation, and integration into an existing inquiry.

AI-mediated absorption can become a form of second-order generativity when the processed resources enlarge subsequent capacities for questioning, recombination, or further acquisition. The resulting effect can therefore propagate beyond the immediate research task.

8.2 Practically Capitalizable Knowledge

This subsection develops the distinction between accessible knowledge and practically capitalizable knowledge. Its role is to connect AI-mediated absorption with the capitalization functions introduced in Subsection 7.4. The analysis examines how technical mediation can enlarge the subset of a public epistemic field that becomes usable within a particular actor’s generative configuration.

Let $K_{\text{accessible}}$ denote epistemic resources that an actor can legally and technically access, and let K_{pc} denote the subset that can be practically capitalized under the actor’s current generative conditions. AI

can change the relation between these sets by modifying search, translation, interpretation, processing, and recombination costs.

The relevant relation is shown in Equation 39.

$$K_{pc}(A, I_{AI}) \subseteq K_{accessible}, \quad \Delta I_{AI} > 0 \implies \Delta |K_{pc}| > 0 \text{ under some conditions.} \quad (39)$$

Equation 39 represents the possibility that stronger AI-mediated infrastructure I_{AI} increases the portion of accessible knowledge that actor A can practically incorporate into epistemic production.

The relationship remains conditional upon complementary capacities. Domain knowledge influences whether generated summaries or associations can be evaluated. Data access affects whether an identified hypothesis can be tested. Compute determines which models or datasets can be processed. Language, institutional resources, time, and methodological competence continue to shape capitalization.

AI therefore changes capitalization capacity through interaction with existing resources. Its generative consequence depends upon the actor-infrastructure- resource configuration examined throughout the preceding sections.

This distinction has an important implication for public knowledge. Expansion of the practically capitalizable subset can increase the effective productive value of a commons even when the legal availability of the commons remains unchanged. A technological change in the means of epistemic processing can therefore transform the political economy of an existing public resource field.

8.3 Infrastructural Epistemic Capital

This subsection develops *infrastructural epistemic capital* as a category for AI systems whose productive significance lies in their capacity to mediate large portions of future epistemic activity. Its objective is to distinguish personally embodied knowledge from control over technical systems capable of searching, processing, generating, and organizing knowledge at scale.

An AI model, compute environment, retrieval system, vector database, scientific workflow, agent orchestration layer, or integrated research platform can contribute to epistemic generativity across many individual tasks. Once constructed, such infrastructure can become reusable across subsequent cycles of production.

Its capital-like property arises from this repeated generative consequence. The infrastructure can lower the cost of later search, synthesis, classification, modeling, drafting, or experimentation. Previous investment in the system thereby changes the productive conditions of subsequent epistemic activity.

Infrastructural epistemic capital can also aggregate capabilities that exceed the embodied knowledge of any single controller. An organization can possess access to models, compute, databases, software, and automated workflows capable of operating across domains beyond the direct expertise of its managers or owners.

This configuration intensifies the distinction developed in Subsection 3.13. Embodied epistemic capital concerns knowledge and generative capacities held by persons. Infrastructural epistemic capital concerns productive capacities instantiated in technical and organizational systems. Control over the latter can become a relational source of epistemic power.

The OECD analysis of AI in science identifies high-performance computing, digital research infrastructure, knowledge bases, AI tools, and access to technical capabilities as important components of contemporary scientific capacity [15]. Within the present framework, these components can be analyzed according to their contribution to future generativity and their distribution across actors.

8.4 Machine-Scaled Epistemic Production

This subsection examines changes in the scale of epistemic production made possible by AI-mediated automation and parallelism. Its role is to extend the throughput analysis of Subsection 4.9 toward systems in which multiple epistemic operations can be performed at machine speed or distributed across computational processes.

Traditional research already relies extensively on machines for measurement, calculation, simulation, storage, and communication. Contemporary AI expands the range of epistemic operations susceptible to computational mediation. Literature screening, classification, extraction, translation, candidate generation, code production, model fitting, data analysis, and preliminary textual synthesis can enter automated or semi-automated workflows.

The resulting transformation concerns scale as well as speed. A computational system can process many candidate inputs in parallel, generate multiple alternative outputs, compare larger sets of possibilities, and repeat standardized operations across extensive corpora.

Machine-scaled production can consequently increase epistemic throughput. Throughput gains become especially significant where workflows divide a larger research process into many partially separable tasks. Different models or agents can perform retrieval, synthesis, criticism, coding, verification, and redrafting within an orchestrated system.

Scale introduces additional requirements for filtering and evaluation. Producing more candidate outputs increases the demand for selection among them. The value of machine-scaled generation therefore depends upon mechanisms for quality assessment, validation, provenance, error detection, and integration.

Machine scaling also changes the allocation of scarce resources. Human attention can migrate from direct execution of every epistemic operation toward task specification, evaluation, integration, judgment, and governance of automated processes. The resulting reorganization of epistemic labor becomes politically significant when control over the relevant infrastructure is unequally distributed.

8.5 Automated Question-Space Expansion

This subsection applies the inquiry possibility-space framework of Subsection 3.10 to AI-mediated generation. Its objective is to examine how computational systems can enlarge the number and diversity of candidate research trajectories available for subsequent evaluation.

Question formulation is itself a generative epistemic activity. AI systems can assist in generating alternative hypotheses, identifying missing comparisons, mapping adjacent literatures, proposing variables, detecting tensions among claims, and producing branches from an initial research problem.

A simplified branching process is shown in Equation 40.

$$Q_0 \longrightarrow \{Q_1, \dots, Q_n\} \longrightarrow \{\Omega_1, \dots, \Omega_n\} \longrightarrow \{K'_1, \dots, K'_m\}. \quad (40)$$

Equation 40 represents computational expansion from an initial question Q_0 toward multiple candidate questions and corresponding inquiry possibility spaces.

The principal gain concerns option generation. A human researcher can inspect a broader range of possible formulations before committing substantial resources to a smaller number of trajectories. AI can also facilitate repeated reformulation by testing a question against several literatures or conceptual frames.

The generative significance of branching depends upon evaluation. Large numbers of syntactically plausible questions can have little epistemic value when they repeat established problems, ignore disciplinary constraints, or lack tractable evidentiary pathways. Human and institutional judgment therefore remain part of the capitalization process.

Automated question-space expansion can nevertheless alter competitive and distributional dynamics. Actors with greater computational capacity can explore larger candidate spaces, perform more preliminary analyses, and identify promising directions with lower marginal search costs. Question generation can therefore become another domain in which infrastructural differences influence recursive epistemic advantage.

8.6 Industrialized Epistemic Capitalization

This subsection introduces *industrialized epistemic capitalization* as a provisional category for knowledge-production arrangements characterized by scale, parallelism, workflow decomposition, automation, in-

frastructural investment, and repeated conversion of epistemic inputs into further productive capacity. Its objective is to identify an organizational transformation that extends beyond individual use of AI tools.

Industrialization historically involves changes in productive organization as well as the introduction of particular machines. Within epistemic production, an analogous transformation can occur when knowledge-processing tasks are decomposed, standardized, automated, parallelized, and coordinated through capital-intensive infrastructure.

An industrialized epistemic process can combine large public corpora, proprietary data, foundation models, specialized models, compute clusters, retrieval systems, automated agents, human experts, evaluation systems, and distribution channels. The resulting organization can process epistemic inputs at scales unavailable to an unaided individual researcher.

The concept of industrialized epistemic capitalization concerns the recursive use of this productive organization. Outputs from one cycle can improve models, databases, retrieval systems, prompts, evaluation procedures, reputation, financial resources, or proprietary knowledge bases. These improvements can increase the capacity of the infrastructure to capitalize upon subsequent epistemic inputs.

A stylized recursive process is shown in Equation 41.

$$K_{\text{external}} \longrightarrow I_{\text{AI}} \longrightarrow O_t \longrightarrow \Delta I_{\text{AI}} \longrightarrow O_{t+1}, \quad (41)$$

where K_{external} denotes external epistemic resources, I_{AI} AI-mediated productive infrastructure, and O_t epistemic outputs generated during production cycle t .

Equation 41 represents a regime in which the productive infrastructure itself can be improved through previous cycles.

Industrialized epistemic capitalization therefore differs in scale and organization from ordinary machine assistance. Its defining features concern the systematic conversion of epistemic inputs through reproducible, infrastructure-mediated productive processes.

8.7 Capital Intensity in Epistemic Production

This subsection examines the growing role of financial and infrastructural resources in some forms of AI-mediated epistemic production. Its objective is to connect AI capabilities with the cross-capital conversion framework developed in Subsections 4.8 and 7.8.

AI systems require heterogeneous quantities of compute, data, technical labor, energy, storage, software, and supporting infrastructure. Some uses remain available through inexpensive consumer services or open-source tools, while frontier-scale training, large experimental programmes, extensive agent deployment, and specialized scientific computing can require substantial resources.

Financial capital can therefore be converted into epistemic throughput through compute and infrastructure. Infrastructural capital can then support larger search spaces, more parallel experiments, broader data processing, or faster iteration. Successful epistemic outputs can subsequently generate reputation, investment, market position, or additional infrastructure.

The result is a potentially strong cross-capital cycle linking financial, infrastructural, and epistemic resources.

Capital intensity can also change the relative importance of constraints. Where human attention previously constituted the principal bottleneck, machine automation can shift part of the constraint toward compute, model access, technical infrastructure, data, and the capacity to coordinate automated systems.

This shift remains domain-specific. Many forms of philosophical, theoretical, historical, qualitative, and small-scale empirical inquiry continue to depend heavily upon individual judgment and modest material infrastructure. Capital-intensity analysis therefore requires specification of the epistemic process under study.

The broader political-economic significance lies in the conversion relation: financial and infrastructural differences can become differences in practical epistemic capitalization capacity.

8.8 Direct Epistemic Labor and Epistemic Output

This subsection examines the changing relation between direct human epistemic labor and the quantity of epistemic output produced under AI-mediated conditions. Its role is to connect machine scaling with the relational distinction between those who perform productive activity and those who control productive infrastructure.

Knowledge production has historically combined direct intellectual labor with tools, institutions, accumulated literature, and distributed contributions. AI increases the range of epistemic operations that can be delegated to technical systems. A controller can therefore organize a larger productive process while personally performing a smaller proportion of retrieval, classification, drafting, coding, or preliminary synthesis.

This relation is especially relevant to the concept of the knowledge capitalist. A knowledge-capitalist position can involve control over systems capable of coordinating large epistemic processes while direct embodied knowledge remains distributed among employees, contractors, public contributors, previous authors, datasets, technical systems, and external communities.

The distinction also applies within individual research practice. A scholar can use AI to shift personal labor from repetitive information processing toward question formulation, conceptual judgment, interpretation, and validation. Such use can increase personal generativity without producing a capitalist relation.

The relevant analytical variable is therefore the organization of epistemic labor under a specified control structure. Automation changes the distribution of productive tasks, while the political-economic meaning of that change depends upon ownership, control, dependency, recognition, appropriation, and circulation.

This distinction prepares a later epistemological problem concerning the relation between epistemic production and knowing. AI-mediated output can expand rapidly while the epistemic transformation of the human participants follows a different trajectory. The present paper preserves that issue as an open extension developed more fully in subsequent work.

8.9 Control of Knowledge-Generating Capacity

This subsection extends enclosure analysis from completed epistemic products to the infrastructure through which future knowledge can be generated. Its objective is to identify control over generative capacity as a potentially distinct object of contemporary political economy.

Traditional intellectual-property analysis often focuses on completed works, inventions, databases, software, or other identifiable outputs. AI-mediated epistemic infrastructure creates an additional layer of control. Models, compute, retrieval systems, proprietary data pipelines, evaluation systems, agent frameworks, and interfaces can govern access to productive capabilities that operate across many future tasks.

Public knowledge can contribute to the construction or operation of these systems. Once incorporated into privately governed infrastructure, the resulting capacity can support future epistemic production under access conditions established by the infrastructure controller.

The relevant trajectory is shown in Equation 42.

$$K_{\text{public}} \longrightarrow I_{\text{controlled}} \longrightarrow G'_{\text{controlled}} \longrightarrow K'_{\text{future}}. \quad (42)$$

Equation 42 represents a process in which public epistemic resources contribute to controlled infrastructure that subsequently mediates future knowledge generation.

The political-economic object therefore becomes control over the means of future epistemic production. Completed public knowledge can remain widely available while practical capacity for machine-scaled capitalization becomes concentrated within infrastructures that require substantial financial, technical, or institutional resources.

This mechanism creates a deeper form of path dependence. Control accumulated during one technological period can shape the distribution of capitalization capacity in subsequent periods. Infrastructure constructed from previous knowledge becomes a condition for later knowledge production.

The jurisprudential status of such transformations depends upon copyright, contract, database rights, competition law, data governance, licensing, and other legal structures. The present section identifies the generative relation while reserving detailed legal evaluation for the Discussion and subsequent jurisprudential work.

8.10 AI and Capitalization Asymmetries

This subsection integrates the preceding mechanisms through the concept of capitalization asymmetry. Its objective is to examine how AI can alter existing differences among actors and generate new differences through uneven access to models, compute, data, expertise, infrastructure, and organizational capacity.

AI can broaden epistemic access in several ways. Low-cost language assistance can reduce linguistic barriers. Search and summarization can reduce the time required for preliminary literature exploration. Code generation can lower technical entry costs for some computational tasks. Public models and open tools can make previously specialized capabilities available to independent researchers and smaller organizations. The OECD report consequently treats broader access to AI capabilities as an important issue for scientific development, including research systems in developing countries [15].

The same technological environment contains significant complementary inequalities. Actors differ in access to frontier models, high-performance compute, proprietary datasets, specialized technical teams, institutional resources, evaluation capacity, and the ability to deploy systems at scale. These differences influence the quantity of public knowledge that becomes practically capitalizable and the rate at which resulting outputs can be converted into further resources.

AI can therefore interact with capitalization asymmetry in multiple directions. Some applications can reduce barriers by lowering the cost of particular epistemic operations. Other configurations can amplify existing advantages by allowing actors with stronger complementary capital to process larger resource fields, explore more candidate trajectories, and reinvest gains into further infrastructure.

The distributive consequence is therefore determined by the surrounding generative configuration. AI has no single predetermined relation to epistemic equality. Its effects depend upon public infrastructure, pricing, model access, compute distribution, skills, institutional governance, open-source ecosystems, data regimes, and mechanisms of recirculation.

This conditional conclusion is important for the foundational framework. Artificial intelligence can change the coefficients, bottlenecks, and scales of knowledge-capital expansion while leaving the more general analytical problem intact: actors encounter shared epistemic fields through heterogeneous capitalization capacities and relational positions.

The AI case consequently reinforces the distinction at the center of the paper. Rapid expansion of epistemic output is a dynamical phenomenon. Concentration of control over the infrastructure enabling that expansion is a relational phenomenon. Their interaction determines the political-economic configuration of AI-mediated knowledge production.

The mechanisms developed in this section remain a bounded application of the general framework. A fuller analysis of industrialized epistemic capitalization, automated epistemic labor, compute-intensive accumulation, and AI-mediated enclosure requires dedicated treatment. Section 9 therefore returns to the broader implications of the framework, including accumulation without capitalist relations, generative extraction, responsibilities toward knowledge commons, ownership and stewardship, and the relation between knowledge production and epistemic formation.

9 Discussion

This section interprets the framework developed in Sections 3–8 and clarifies its theoretical, normative, jurisprudential, and epistemological implications. Its role is synthetic. The discussion first returns to the meaning of capital within the proposed framework and to the distinction between expansion dynamics and relational position. It then examines how accumulation can occur across different institutional configurations and how publicness interacts with unequal capitalization capacity. The middle part develops the relations among appropriation, extraction, exploitation, generative return, and commons regeneration. The subsequent subsections consider ownership, provenance, stewardship, licensing, and governance of generative infrastructure. The final part discusses artificial intelligence and the relation between epistemic production and epistemic formation before locating the present paper within the wider research programme.

9.1 Knowledge-Capital Expansion and Capital Terminology

This subsection evaluates the scope of the capital vocabulary introduced in the paper. Its objective is to clarify which structural features motivate the analogy and which historical meanings of capital remain specific to their original political-economic contexts.

The literature review showed that *capital* has carried several related meanings across political economy. Classical political economy associates capital with accumulated productive resources. Marx develops a dynamic account in which capital passes through processes of valorization, accumulation, reproduction, concentration, and centralization [13]. Human-capital theory extends capital language toward embodied productive capacities [2]. R&D-based knowledge-capital research operationalizes accumulated research investment through productivity analysis [7]. Intellectual-capital research applies capital terminology to organizationally embedded intangible resources [3], while Bourdieu broadens the concept toward cultural and social accumulation and conversion [4].

The present framework enters this conceptual field through a specific criterion: generative consequence across time. An epistemic resource acquires a capital-like character when its possession, access, or control changes the conditions of subsequent epistemic production. The concept therefore centers on recursive productive consequence.

This criterion gives knowledge capital a wider extension than expenditure-based R&D capital and a narrower extension than the totality of information or knowledge. A resource that remains disconnected from subsequent generative activity has limited relevance to the concept. A resource that changes what can later be understood, asked, combined, investigated, or produced becomes analytically significant.

The term *knowledge-capital expansion* consequently identifies a family of dynamical processes. Accumulation, reproduction, recombination, question-space expansion, cross-capital conversion, concentration, and infrastructural development can all contribute to expansion while retaining distinct causal structures.

This broader use of capital terminology should therefore remain explicitly provisional. Its analytical value depends upon whether it reveals recursive structures that adjacent vocabularies leave insufficiently visible. Later historical and empirical research can determine where the analogy provides explanatory gain and where more specific terminology should replace it.

9.2 Expansion Dynamics and Relational Position

This subsection returns to the principal conceptual distinction of the paper. Its objective is to clarify the analytical consequences of separating knowledge-capital expansion from positions within relations of epistemic production.

The distinction can be summarized through two different questions. Dynamical analysis concerns how epistemic resources and generative capacities change through time. Relational analysis concerns how actors are positioned with respect to productive conditions, labor, control, access, appropriation, and dependency.

A high rate of epistemic expansion therefore supplies limited information about an actor's relational position. A researcher can accumulate knowledge rapidly through publicly available resources while exercising little control over the conditions of other actors' production. A cooperative research community can develop powerful shared epistemic infrastructure while distributing governance among participants. A commercial platform can control extensive productive infrastructure while the individuals exercising corporate authority possess limited direct knowledge of the epistemic content processed through the system.

The distinction also clarifies the meaning of the knowledge-capitalist category. The category refers to a position characterized by substantial control over means or conditions of epistemic production and the capacity to organize, direct, scale, or appropriate epistemic production. It therefore belongs to a relational analysis rather than to a ranking of individual intelligence, expertise, or output.

The two dimensions can nevertheless become strongly coupled. Successful knowledge-capital expansion can generate reputation, finance, infrastructure, or institutional authority. These converted resources can increase control over future productive conditions. Conversely, prior control over productive conditions can accelerate epistemic accumulation.

The conceptual contribution lies in preserving the distinction while analyzing the coupling. Capital-like expansion concerns a trajectory. Capitalist position concerns a relation. Their interaction constitutes a central object of the political economy of knowledge production.

9.3 Accumulation across Relational Configurations

This subsection considers the institutional diversity of knowledge-capital accumulation. Its objective is to show how similar dynamical patterns can occur within different structures of circulation, governance, and control.

Recursive epistemic accumulation can occur through individual study, university research, scientific collaboration, public institutions, cooperatives, open-source communities, firms, informal scholarly networks, and other organizational forms. Each configuration combines generative conditions through different arrangements of ownership, authority, labor, funding, and circulation.

The existence of accumulation therefore provides only one layer of analysis. Its political meaning depends upon the relations through which resources are produced and governed.

This distinction permits a clearer comparison between proprietary and socialized accumulation. Proprietary accumulation concentrates resulting capacities within restricted systems of control. Socialized accumulation returns substantial portions of resulting resources or infrastructure to shared generative conditions.

The two configurations can produce similar short-term output growth while differing substantially in their long-term effects on field-level generativity. A proprietary trajectory can increase one actor's capacity while reducing effective access to future productive infrastructure. A socialized trajectory can increase individual or institutional capacity while simultaneously expanding the commons from which later actors can generate.

The normative significance of accumulation therefore emerges through the governance of its resulting capacities.

9.4 Publicness, Openness, and Distribution

This subsection interprets the openness–concentration relation developed in Section 5. Its objective is to clarify the distinction between expansion of shared availability and distribution of effective capitalization capacity.

Knowledge-commons scholarship has established the importance of access, governance, preservation, and enclosure in shared knowledge environments [9]. The present framework adds a distributional question concerning what actors can do with accessible resources after access has been secured.

Public availability can increase the generative potential of a field while leaving substantial differences in prior knowledge, language, infrastructure, time, funding, networks, and institutional position. These

differences shape capitalization capacity.

The resulting distributional problem is therefore located between access and future generativity. Openness can enlarge the common resource field while actors extract heterogeneous generative gains from that field.

This relation has two implications for commons governance.

The first concerns aggregate effects. Policies that expand public access can increase total field-level generativity even when distributional differences remain.

The second concerns distributional effects. Evaluation of a commons can also consider whether actors possess practical conditions required to capitalize upon shared resources.

The openness–concentration paradox therefore identifies a possible coexistence between common-resource expansion and concentration of effective generative capacity. Its significance lies in directing analysis toward the complementary infrastructures and capacities surrounding public access.

9.5 Appropriation, Extraction, and Exploitation

This subsection clarifies the sequence connecting capitalization, appropriation, generative extraction, and generative exploitation. Its objective is to preserve distinctions among increasingly strong relational descriptions.

Epistemic capitalization concerns conversion of a resource into enhanced future generative capacity. Appropriation concerns incorporation of generated or shared value into an actor's controllable accumulation process. Generative extraction concerns a systematic pattern in which a source field contributes generative resources while the resulting increase in capacity is disproportionately retained elsewhere. Generative exploitation adds stronger conditions concerning degradation, suppression, dependency, subordination, or loss of the source's future generativity.

The progression is therefore analytically cumulative. Each concept adds relational information beyond the preceding category.

This distinction is especially important in public knowledge environments. Every productive use of public knowledge involves some form of individual or institutional gain. Such gain constitutes a central purpose of a knowledge commons. A stronger normative concern emerges when gains become connected to one-directional circulation, concentrated control, dependency, or degradation of the generative field from which those gains were derived.

Generative justice provides an important normative orientation here because it directs attention toward the circulation of generated value and regeneration of source communities and systems [5]. The present framework extends this orientation toward recursive epistemic capacity.

The normative threshold between appropriation, extraction, and exploitation requires further analysis. Consent, reciprocity, dependence, substitutability, distribution of control, regeneration of source conditions, and long-term effects on participants can all become relevant variables.

9.6 Ethical Boundaries of Knowledge-Capital Accumulation

This subsection identifies the principal ethical questions generated by the framework. Its role is diagnostic: it specifies where descriptive analysis creates normative problems while leaving systematic ethical criteria to the subsequent dedicated inquiry.

Knowledge-capital accumulation can increase individual and collective generativity. It can support education, scientific discovery, cultural development, institutional learning, and technological progress. Ethical analysis therefore requires attention to both the generative gains produced by accumulation and the relations through which those gains arise.

Several dimensions become relevant.

The first concerns effects on the generativity of other actors. An accumulation process can enlarge one actor's capacity while leaving others unchanged, increasing their capacity through recirculation, or constraining their future possibilities through enclosure or dependency.

The second concerns the origin of generative resources. Public knowledge, collective labor, community knowledge, institutional infrastructure, and individual contributions can enter an accumulation process through different relations of consent, attribution, compensation, and recognition.

The third concerns control over resulting capacities. The ethical significance of an epistemic output can differ from the significance of exclusive control over infrastructure capable of producing large classes of future outputs.

The fourth concerns reversibility and dependency. A productive arrangement can become ethically more consequential when participants lose practical capacity to exit, reconstruct their generative conditions, or continue producing outside the controlling infrastructure.

The fifth concerns circulation. Accumulated capacity can return to the commons through knowledge, infrastructure, education, funding, or other generative resources.

Epistemic-injustice scholarship adds an additional dimension by showing how credibility, interpretive resources, and epistemic participation can be shaped by relations of power [6]. A political economy of knowledge capital therefore intersects with questions concerning who can participate as a recognized knower and whose contributions enter processes of future accumulation.

These considerations motivate a dedicated ethics of knowledge-capital accumulation capable of distinguishing productive asymmetry from extraction and stronger forms of generative exploitation.

9.7 Generative Return and Commons Responsibilities

This subsection develops *generative return* as a possible normative and governance problem arising from the use of shared epistemic resources. Its objective is to clarify the forms that return can take before any universal duty of return is specified.

Generative return refers provisionally to contributions that restore, enlarge, or reproduce the generative conditions from which an actor has benefited. Return can occur through several channels.

An actor can return epistemic outputs through publications, concepts, data, software, translations, methods, or educational materials. An organization can contribute infrastructure, funding, standards, documentation, or institutional support. A researcher can return value through teaching, reviewing, mentoring, maintenance of shared resources, or participation in collaborative governance.

The form of return can therefore differ from the form of the resource initially used. Public literature can contribute to private expertise, while the resulting return can take the form of new open methods or teaching. Public infrastructure can support commercial innovation, while return can occur through taxation, public investment, open standards, or other institutional mechanisms.

Generative return should therefore be understood through functional effects on future generativity. The central question concerns whether subsequent contributions regenerate shared conditions of production.

The existence, magnitude, and form of any ethical or legal duty of return remain open. Different commons can operate through different norms of reciprocity, contribution, attribution, taxation, licensing, or public support. A universal rule could obscure these institutional differences.

The concept is therefore introduced as an analytical bridge between the dynamics of recirculation and the later ethics of commons participation.

9.8 Ownership, Possession, Control, and Appropriation

This subsection returns to the distinctions developed in Subsection 6.11 and interprets their jurisprudential significance. Its objective is to prevent legal ownership from becoming a proxy for every practical relation governing epistemic resources.

Ownership concerns a legally recognized configuration of rights. Possession concerns factual holding or access. Control concerns practical capacity to govern use, allocation, circulation, modification, or continuation. Appropriation concerns incorporation of generated or shared value into a controllable accumulation process.

These relations can diverge substantially in knowledge systems. A public-domain work can be freely possessed while practical use at scale depends upon proprietary infrastructure. An organization can exercise technical control over content whose copyright belongs elsewhere. An author can retain legal rights while permitting broad reproduction and modification. A platform can mediate circulation without owning every underlying epistemic object.

The distinction becomes increasingly important as productive power moves toward infrastructure. Legal analysis focused exclusively on ownership of completed outputs can miss practical control over the conditions through which future outputs are generated.

The present framework therefore treats ownership as one component within a wider architecture of epistemic governance. Detailed jurisprudential analysis must examine the legal instruments through which ownership, permission, attribution, access, control, and remedy are configured in specific jurisdictions.

9.9 Priority, Provenance, and Proprietorship

This subsection distinguishes historical priority and provenance from proprietary control. Its objective is to identify a possible basis for recognition and accountability compatible with broad circulation of epistemic resources.

Priority concerns historical relation to the development, discovery, articulation, or publication of an epistemic contribution. Provenance concerns the traceable history through which an epistemic resource, claim, dataset, method, or artifact emerged and circulated. Proprietorship concerns legally or institutionally recognized control over specified uses.

These relations need not coincide.

A concept can have identifiable historical origins while remaining available for unrestricted intellectual use. A dataset can require strong provenance records for verification and accountability while supporting broad reuse. An author can retain attribution and integrity interests while permitting substantial reproduction and transformation.

The present framework therefore preserves the possibility of *priority without proprietorship* as a normative and jurisprudential direction. Recognition of epistemic contribution can be separated analytically from exclusive conceptual control.

This distinction has particular importance for a generative commons. Provenance can support attribution, historical accountability, error tracking, and recognition of contributors while circulation supports future recombination and generation.

The legal implementation of this separation requires dedicated analysis across copyright, moral rights, database rights, contractual arrangements, licensing, and other relevant legal regimes. The present paper identifies the conceptual distinction and leaves its institutional realization open.

9.10 Legal Ownership and Epistemic Enclosure

This subsection examines the relation between legal ownership and enclosure. Its objective is to clarify why identifiable rights and restricted generative circulation should be treated as separate analytical variables.

Legal rights can support several functions relevant to an epistemic commons. They can identify responsible parties, preserve attribution, support integrity, define permissions, and provide mechanisms for remedy. The same or related rights can also support exclusion, licensing restrictions, or control over circulation.

The jurisprudential problem therefore concerns the configuration of rights. Different combinations of attribution, reproduction, modification, distribution, commercial use, integrity, and remedial powers can produce different effects on future generativity.

Enclosure should consequently be examined functionally. A legal arrangement becomes relevant to knowledge-capital analysis when it materially constrains access to epistemic resources or conditions required for subsequent generation.

Technical and institutional mechanisms can produce similar effects independently of formal ownership. Access controls, proprietary formats, platform dependencies, compute restrictions, contractual arrangements, and organizational authority can all shape generative circulation.

The relation between legal ownership and epistemic enclosure is therefore contingent upon the rights, infrastructures, and governance arrangements surrounding the resource.

9.11 Stewardship and Commons Governance

This subsection develops stewardship as a possible governance orientation for epistemic resources whose circulation and preservation involve continuing responsibilities. Its objective is to identify an institutional direction between unrestricted abandonment of responsibility and strongly exclusionary control.

Stewardship refers here to governance oriented toward preservation, provenance, accessibility, integrity, responsible circulation, and future generativity. The steward can possess particular legal or institutional powers while exercising them in relation to continued functioning of a shared epistemic resource.

Knowledge-commons scholarship provides an important foundation for this orientation because commons governance concerns institutional arrangements through which shared resources are created, maintained, and sustained [9].

A stewardship model can be relevant where complete relinquishment of control creates risks to preservation, provenance, integrity, or accountability. Archives, datasets, standards, software repositories, and community knowledge can require maintenance and governance over long periods.

The concept also raises substantial questions. Stewardship authority can become concentrated. Protective powers can develop into exclusionary control. Communities can disagree over legitimate custodianship. Legal ownership, technical maintenance, moral responsibility, and collective governance can be distributed among different actors.

Stewardship therefore functions here as a research direction rather than a settled institutional solution. Its value lies in focusing governance on the reproduction of generative conditions.

9.12 Licensing and Rights Architecture

This subsection identifies licensing as one possible mechanism for governing the relation among circulation, attribution, use, and control. Its objective is to define the conceptual questions that a later jurisprudential inquiry must address.

A generative-commons approach can value broad reproduction, modification, citation, teaching, research use, and cross-domain recombination. The same approach can also value provenance, attribution, integrity, accountability, and protection against particular forms of harmful appropriation or enclosure.

These interests do not necessarily map onto a single legal permission. Different legal systems distinguish among copyright, moral rights, contracts, database rights, patents, confidentiality, personality interests, and other legal categories. Their scope also varies across jurisdictions.

The jurisprudential task therefore concerns the architecture of rights and permissions required for a specific kind of epistemic resource.

Several questions become central: which forms of use should remain broadly available; which forms of attribution are necessary for provenance; which integrity interests justify intervention; which powers facilitate enclosure; which remedial mechanisms preserve accountability; and how legal arrangements affect subsequent generative circulation.

The present paper leaves these questions open. A later jurisprudential inquiry can examine existing open licenses, public-domain mechanisms, retained-rights models, attribution regimes, and possible stewardship-oriented structures against the generative criteria developed here.

9.13 AI, Generative Capacity, and Governance

This subsection interprets the AI analysis of Section 8 through the wider governance framework. Its objective is to clarify why control over machine-scaled generative capacity can become a distinct political-economic object.

AI can enlarge the practical amount of public knowledge that an actor can search, synthesize, translate, recombine, and convert into future generative capacity. It can also increase throughput and automate portions of epistemic labor. The OECD review of AI in science demonstrates the growing importance of AI capabilities, compute infrastructure, research governance, and differential access within scientific systems [15].

These developments make complementary resources increasingly important. Compute, model access, data, technical expertise, orchestration systems, evaluation infrastructure, and institutional capacity can determine the scale at which AI-mediated capitalization becomes possible.

Governance therefore extends beyond individual AI outputs. The distribution of model access, compute, infrastructure, interoperability, data, and technical standards can shape the future distribution of epistemic generativity.

This perspective reframes one dimension of AI political economy. Public knowledge can remain widely accessible while the ability to capitalize upon it at machine scale becomes concentrated. A central governance problem therefore concerns the distribution and control of knowledge-generating capacity.

The problem also intersects with commons regeneration. AI infrastructures can draw upon public research, open software, public data, and collective cultural resources while producing new private capabilities. The resulting circulation patterns raise questions concerning generative return, access, attribution, competition, stewardship, and public infrastructure.

These issues require a dedicated AI-specific political economy. The present paper identifies their relation to the foundational framework.

9.14 Knowledge Production and Epistemic Formation

This subsection considers an epistemological implication that emerges when knowledge production becomes increasingly mediated by high-throughput and automated systems. Its objective is to distinguish expansion of epistemic output from changes in the capacities of the knowing subject.

Knowledge-capital expansion has so far been analyzed through the production and reproduction of epistemic resources and generative capacity. Human knowing, however, also involves processes of learning, interpretation, conceptual formation, judgment, experience, and transformation of the epistemic subject.

AI can increase output while changing the relation between the subject and the process through which that output was produced. A system can retrieve literature, generate a synthesis, write code, or construct candidate arguments before the human participant has personally traversed the corresponding epistemic path.

The resulting distinction concerns *knowledge production* and *epistemic formation*. The first concerns generation of epistemic artifacts or claims. The second concerns development of the subject's capacity to understand, judge, question, and generate.

The distinction has affinities with the concern for conditions of cognition introduced through Kantian epistemology in Subsection 2.6. Access to representations and production of representations do not exhaust the conditions under which a subject develops durable epistemic capacities.

Some forms of knowing can also depend upon embodied, relational, situated, or temporally extended processes. Their capitalization dynamics can differ from those of codified resources.

This problem extends beyond the scope of the present political economy. Subsequent work must examine the relation between automated knowledge production, direct encounter with epistemic objects, friction in learning, formation of judgment, and preservation of epistemic agency.

9.15 Implications for the Research Programme

This subsection locates the foundational framework within the broader research programme. Its objective is to distinguish the problems established by the present paper from the specialized inquiries required for further development.

The present paper establishes knowledge capital, knowledge-capital expansion, epistemic capitalization, capitalization capacity, capitalization asymmetry, recursive epistemic advantage, public knowledge as generative infrastructure, knowledge-capitalist and epistemic-proletarian positions, generative extraction, and related analytical distinctions.

Several branches follow from this foundation.

The first concerns the AI-specific political economy of industrialized epistemic capitalization. This branch examines machine-scaled production, compute, infrastructure, automation, and concentration of knowledge-generating capacity.

The second concerns jurisprudence. This branch examines licensing, retained rights, provenance, attribution, stewardship, integrity, ownership, and enclosure within specific legal regimes.

The third concerns ethics. This branch develops criteria for distinguishing productive accumulation, appropriation, generative extraction, exploitation, recirculation, and responsibilities toward knowledge commons.

The fourth concerns material and institutional praxis. This branch examines how actors with limited financial, infrastructural, or institutional capital can sustain generativity within unequal knowledge fields.

The fifth concerns epistemology. This branch examines knowing, epistemic formation, direct encounter, embodied and relational knowledge, and the conditions under which AI-mediated production contributes to or bypasses epistemic development.

The sixth concerns philosophical method and record. This branch examines the role of human–AI dialogue in philosophical inquiry and the relation among raw dialogue, analytical commentary, and stabilized academic publication.

The value of the foundational framework therefore lies partly in its capacity to generate differentiated research questions. The concepts introduced here provide a common vocabulary while the later branches retain distinct objects, literatures, methods, and normative commitments.

Section 10 consequently turns from synthesis toward the unresolved conceptual, empirical, normative, jurisprudential, epistemological, and methodological problems that define the next stages of the research programme.

10 Open Problems and Research Directions

This section identifies the unresolved problems that follow from the foundational framework developed in the preceding sections. Its role is to separate concepts established provisionally in the present paper from questions that require further philosophical, historical, empirical, normative, jurisprudential, or methodological investigation. The section is organized by research function. It begins with conceptual boundaries and ontology, then turns to temporal dynamics, capitalization and distribution, cross-capital conversion, relations of epistemic production, commons circulation, normative questions, jurisprudential questions, artificial intelligence, epistemic formation, and empirical methodology. The purpose is to preserve the openness of the research programme while providing a structured agenda for subsequent work.

10.1 Conceptual Boundaries of Knowledge Capital

This subsection identifies unresolved questions concerning the scope and internal structure of the concept of knowledge capital. Its objective is to clarify which epistemic resources should fall within the category and which conceptual distinctions require further refinement before empirical operationalization.

10.1.1 Boundary of the Knowledge-Capital Category

The principal conceptual boundary concerns the threshold at which an epistemic resource becomes sufficiently generative across time to justify treatment as capital. The present paper uses generative consequence as the provisional criterion, yet later work must determine whether this criterion requires additional conditions such as persistence, reproducibility, transferability, convertibility, or participation in recursive accumulation.

10.1.2 Relation among Capital, Capitalization, Accumulation, and Expansion

The framework distinguishes knowledge capital, epistemic capitalization, accumulation, and knowledge-capital expansion. Their precise relations require further conceptual refinement. Capitalization concerns conversion of resources into future generative capacity. Accumulation concerns growth or persistence of resources. Expansion concerns a wider family of recursive trajectories. Later work should determine whether additional distinctions are required among reproduction, amplification, scaling, concentration, and conversion.

10.1.3 Scope of the Capital Analogy

The explanatory value of the capital analogy requires systematic comparison with alternative vocabularies such as capacity, resource, competence, infrastructure, capability, repertoire, and generative condition. The analogy should be retained where it reveals recursive productive structure and cross-capital conversion with greater precision than those alternatives.

10.1.4 Ontology of Epistemic Resources

The framework currently places propositions, questions, concepts, methods, datasets, tools, embodied capacities, and relational resources within a common analytical field. These resources differ substantially in persistence, transferability, embodiment, divisibility, reproducibility, and dependence upon context. A more developed ontology of epistemic resources is therefore required.

10.1.5 Questions and Possibility Spaces

Questions have been treated as possible forms of epistemic capital because they can enlarge future inquiry spaces. Further research should distinguish questions that merely restate existing problems from questions that materially reorganize the set of possible investigations. The concept of an inquiry possibility space also requires formal and philosophical development.

10.1.6 Units of Knowledge Capital

The appropriate unit of analysis remains unresolved. Knowledge capital can appear in individuals, groups, institutions, infrastructures, archives, or fields. The relations among these levels require clarification, particularly when epistemic resources are distributed across several actors and cannot be localized within a single holder.

10.2 Temporal Structure and Recursive Dynamics

This subsection identifies unresolved problems concerning the temporal development of knowledge capital. Its objective is to distinguish different forms of recursive expansion and to clarify the conditions under which generative advantages persist, amplify, saturate, or decline.

10.2.1 Temporality of Knowledge-Capital Formation

Knowledge-capital formation can occur over minutes, years, or generations. Some resources generate immediate effects, while others become productive only after later encounters. Future work should therefore distinguish short-term capitalization from delayed and latent generative effects.

10.2.2 Path Dependence

Earlier epistemic states shape the interpretation and use of later resources. The degree of path dependence across different domains remains an empirical and theoretical question. Research should examine when early advantages become persistent and when later structural changes reduce their significance.

10.2.3 Recursive Epistemic Advantage

The mechanisms through which epistemic advantage becomes self-reinforcing require further differentiation. Conceptual mastery, methodological skill, reputation, network access, funding, and infrastructure can all contribute to recursive advantage through different pathways.

10.2.4 Saturation and Diminishing Generativity

Knowledge accumulation can encounter saturation when additional resources add little to future generativity. Attention scarcity, redundancy, specialization, fragmentation, and incompatibility can all produce diminishing returns. A theory of knowledge-capital expansion should therefore include conditions of stagnation and decline.

10.2.5 Discontinuity and Critical Transitions

Some epistemic trajectories can change rapidly following a conceptual, technological, institutional, or methodological transition. Later work should distinguish smooth recursive accumulation from discontinuous reorganizations of the generative system.

10.3 Capitalization Capacity and Distribution

This subsection develops unresolved questions concerning unequal conversion of public epistemic resources into future generative capacity. Its objective is to clarify the determinants, distribution, and long-term consequences of capitalization capacity.

10.3.1 Determinants of Capitalization Capacity

The framework identifies prior knowledge, time, language, funding, networks, institutional position, and infrastructure as possible determinants of capitalization capacity. Their relative importance is likely to vary across domains and historical periods. Empirical research should therefore identify domain-specific configurations.

10.3.2 Capitalization Asymmetry under Formal Equality

Equal legal or technical access can coexist with unequal generative gains. Future work should determine which inequalities have the strongest effects on capitalization and which public interventions most effectively reduce differences in effective use.

10.3.3 Openness and Concentration

The openness–concentration relation requires empirical testing. Research should examine whether broader public access tends to reduce, preserve, or increase concentration of generative capacity under different institutional conditions.

10.3.4 Field-Level and Actor-Level Generativity

An epistemic field can become more productive while individual actors follow divergent trajectories. Future research should distinguish aggregate expansion from the distribution of generative capacity and control.

10.3.5 Concentration and Centralization of Epistemic Capital

The distinction between concentration through internal accumulation and centralization through aggregation of existing resources requires adaptation to knowledge systems. Relevant cases can include mergers of research infrastructures, consolidation of publishing systems, platform acquisition, dataset aggregation, and concentration of compute.

10.4 Cross-Capital Conversion and Recognition

This subsection identifies open questions concerning movement between epistemic, reputational, financial, network, institutional, and infrastructural forms of capital. Its objective is to clarify how cross-capital feedback contributes to recursive expansion and concentration.

10.4.1 Conversion Pathways

The direction, rate, and reversibility of capital conversion remain open. Knowledge can generate reputation, reputation can generate funding, and funding can generate infrastructure, yet these pathways vary substantially across fields and institutions.

10.4.2 Reputation and Visibility

The relation between epistemic value and visibility requires further analysis. High-quality epistemic contributions can receive limited recognition, while highly visible outputs can generate substantial reputational capital. Future work should examine the institutional conditions under which visibility becomes a major conversion mechanism.

10.4.3 Epistemic Throughput

High output volume can become convertible into reputation, institutional position, or financial resources. The degree to which throughput becomes independent of epistemic value is an important problem for contemporary research systems.

10.4.4 Recognition-Control Feedback

Accumulated recognition can provide greater influence over funding, publication, hiring, evaluation, and agenda formation. Research should examine when epistemic capital begins to expand through control over recognition systems rather than primarily through the generative significance of its underlying epistemic resources.

10.4.5 Attention Scarcity

Expanding epistemic output increases competition for limited human and institutional attention. Attention can therefore become a bottleneck and a convertible resource within knowledge-capital dynamics.

10.5 Relations of Epistemic Production

This subsection identifies unresolved questions concerning positions, dependency, labor, and control within epistemic production. Its objective is to develop the relational analysis beyond the preliminary categories introduced in Section 6.

10.5.1 Boundary of the Knowledge-Capitalist Category

The threshold of control required for classification as a knowledge capitalist remains provisional. Future work should distinguish ownership, managerial authority, infrastructural control, funding power, agenda control, and appropriation.

10.5.2 Boundary of the Epistemic-Proletarian Category

The epistemic-proletarian category also requires refinement. Dependency upon externally controlled generative conditions can vary in intensity, duration, and substitutability. The relation between skilled professional autonomy and structural dependency deserves particular attention.

10.5.3 Epistemic Dependency

Future work should develop measures of dependency based on the importance of a resource, availability of substitutes, switching costs, continuity of access, and capacity for independent reconstruction of generative conditions.

10.5.4 Epistemic Subordination

The transition from dependency to subordination requires clearer criteria. Research should examine the degree of control over agenda, pace, method, recognition, circulation, and future opportunity that constitutes a subordinating relation.

10.5.5 Generative Precarity

Generative precarity requires temporal analysis of unstable access to employment, affiliation, infrastructure, funding, platforms, software, and other productive conditions. Its relation to long-term epistemic development remains largely unexplored.

10.5.6 Epistemic Labor under Distributed Production

Contemporary knowledge production distributes work across researchers, technicians, maintainers, data contributors, reviewers, software developers, administrators, and machine systems. Future analysis should examine the distribution of recognition, control, and resulting capital across these forms of labor.

10.6 Commons Circulation and Generative Return

This subsection develops unresolved questions concerning circulation between public epistemic fields and individual or institutional accumulation. Its objective is to clarify the mechanisms through which commons can be regenerated or progressively weakened.

10.6.1 Commons-to-Private Capitalization

Future research should distinguish ordinary private learning from institutionally significant conversion of public knowledge into controlled generative capacity. Scale, control, exclusivity, and recursive advantage are likely to be important variables.

10.6.2 Generative Recirculation

The effectiveness of recirculation depends upon more than formal publication. Research should examine accessibility, interoperability, documentation, discoverability, preservation, and practical reusability.

10.6.3 Generative Return

The concept of generative return requires further development. Return can take epistemic, infrastructural, financial, educational, institutional, or relational forms. Their comparative effects on commons generativity remain open.

10.6.4 Commons Regeneration

A commons can require active maintenance and renewal. Future work should examine which institutional arrangements regenerate public epistemic infrastructure over long periods.

10.6.5 Proprietary and Socialized Accumulation

The ideal types introduced in the present paper require empirical comparison. Research should investigate mixed configurations in which some resources circulate publicly while complementary infrastructure remains restricted.

10.7 Normative Structure of Knowledge-Capital Expansion

This subsection identifies ethical problems generated by the descriptive framework. Its objective is to preserve a clear boundary between the foundational political economy developed here and the later normative theory of knowledge-capital accumulation.

10.7.1 Thresholds of Appropriation

The point at which ordinary capitalization becomes ethically significant appropriation requires further criteria concerning origin, control, reciprocity, dependency, and distribution of resulting capacity.

10.7.2 Generative Extraction

Generative extraction requires specification of sufficient conditions for identifying a one-directional flow from a source field into a private accumulation process. The degree of required asymmetry and the relevant unit of return remain unresolved.

10.7.3 Generative Exploitation

The stronger concept of generative exploitation requires criteria concerning degradation, suppression, dependency, lock-in, or loss of future generativity. These criteria should be developed independently of simple inequality in outcomes.

10.7.4 Responsibilities toward the Commons

The use of public knowledge can generate possible responsibilities toward shared generative conditions. The source, scope, strength, and form of such responsibilities remain open normative questions.

10.7.5 Distribution of Generative Capacity

Ethical analysis should consider the distribution of future generative capacity in addition to current outputs or welfare. A system can produce substantial knowledge while progressively concentrating the means of future generation.

10.7.6 Epistemic Justice and Generativity

The relation between epistemic injustice and knowledge-capital distribution requires further integration. Credibility, interpretive resources, recognition, and access to productive conditions can all affect future generativity.

10.8 Jurisprudential Architecture

This subsection identifies the legal questions generated by the distinction among ownership, possession, control, appropriation, circulation, and stewardship. Its objective is to define a research agenda for a dedicated jurisprudential inquiry.

10.8.1 Ownership and Enclosure

Future research should examine which configurations of legal ownership produce material effects on future epistemic access and generativity. Formal ownership and practical enclosure should remain analytically separate.

10.8.2 Priority and Provenance

The relation among historical priority, attribution, provenance, and legal rights requires systematic analysis. A framework of priority without proprietorship may provide one direction for preserving recognition while supporting broad circulation.

10.8.3 Stewardship and Retained Rights

The possibility of retaining legal rights for provenance, integrity, accountability, or protection while minimizing exclusion requires careful comparative legal study.

10.8.4 Licensing Architecture

Existing licenses distribute permissions differently across reproduction, modification, attribution, commercial use, and derivative production. Their effects on generative circulation should be evaluated against the framework developed here.

10.8.5 Attribution and Integrity

Attribution and integrity can support provenance and accountability while also creating tensions with transformation and reuse. Their role within a generative commons requires jurisdiction-sensitive analysis.

10.8.6 Governance of Shared Generative Infrastructure

Legal research should extend beyond individual knowledge objects toward databases, models, platforms, compute, repositories, and other infrastructures that mediate future epistemic production.

10.9 Artificial Intelligence and Industrialized Capitalization

This subsection develops the AI-specific research programme emerging from Section 8. Its objective is to separate the general theory of knowledge-capital expansion from questions produced by machine-scaled epistemic infrastructure.

10.9.1 Epistemic Absorption Capacity

Further research should measure how AI changes the practical amount and diversity of external knowledge that actors can absorb within fixed temporal, financial, and cognitive constraints.

10.9.2 Industrialized Epistemic Capitalization

The transition from individual AI assistance to industrialized epistemic capitalization requires clearer criteria concerning scale, automation, parallelism, workflow decomposition, infrastructure, and capital intensity.

10.9.3 Automation of Epistemic Capital Reproduction

AI can potentially automate portions of the cycle through which epistemic capital generates further epistemic capital. The degree of automation and the remaining role of human judgment require empirical investigation.

10.9.4 Concentration of Generative Capacity

AI can reduce some barriers while increasing the importance of compute, proprietary data, model access, and technical infrastructure. Future research should examine the resulting distribution of machine-scaled generative capacity.

10.9.5 Human Epistemic Labor

The reorganization of epistemic labor under AI requires analysis of task allocation, deskilling, reskilling, judgment, recognition, responsibility, and control over resulting outputs.

10.9.6 Enclosure of Generative Capacity

A major research problem concerns configurations in which public epistemic resources contribute to privately controlled systems that govern future knowledge generation. This issue extends beyond enclosure of completed epistemic products.

10.10 Epistemic Formation and Limits of Capitalization

This subsection identifies epistemological problems created by the distinction between epistemic output and transformation of the knowing subject. Its objective is to establish the boundary between the political economy developed here and subsequent work on knowing, learning, and epistemic formation.

10.10.1 Knowledge Production and Knowing

The relation between production of epistemic artifacts and development of durable human understanding requires further analysis. AI makes the distinction especially visible.

10.10.2 Direct Encounter and Mediation

Different forms of epistemic mediation can preserve, transform, or weaken the relation between a subject and an object of inquiry. The significance of direct encounter requires domain-specific philosophical analysis.

10.10.3 Embodied and Tacit Knowledge

Embodied skills and tacit capacities may resist the forms of rapid transfer available to codified knowledge. Their accumulation and capitalization dynamics require separate treatment.

10.10.4 Relational and Situated Knowledge

Some knowledge emerges through sustained relations, institutional participation, cultural context, field experience, or interaction with particular communities. Such resources may be difficult to detach from the relations through which they become knowable.

10.10.5 Temporally Irreducible Knowledge

Some epistemic capacities may require extended periods of practice, observation, reflection, or relationship. Future work should examine cases in which time functions as a constitutive condition of knowing.

10.10.6 Epistemic Agency

Increasing automation raises questions concerning preservation of the subject's capacity to formulate questions, evaluate claims, revise conceptual structures, and direct inquiry. These concerns motivate the later epistemic-praxis papers.

10.11 Empirical and Comparative Research

This subsection identifies methodological requirements for moving from the present conceptual framework toward empirical inquiry. Its objective is to clarify possible strategies for operationalization, comparison, and disconfirmation.

10.11.1 Measurement of Knowledge-Capital Expansion

Future work requires measures capable of distinguishing increases in epistemic stock from changes in future generative capacity. Output counts alone provide limited information about recursive expansion.

10.11.2 Measurement of Capitalization Capacity

Capitalization capacity may require composite or domain-specific measures covering prior knowledge, time, infrastructure, language, institutional access, networks, and technical resources.

10.11.3 Measurement of Control and Dependency

Relational categories require operational measures of control over generative conditions, availability of substitutes, switching costs, agenda influence, and continuity of access.

10.11.4 Identification of Recursive Effects

Empirical analysis must distinguish ordinary correlation between prior success and later success from causal mechanisms through which previous epistemic gains alter future capitalization capacity.

10.11.5 Historical Comparison

Knowledge-capital dynamics should be studied across different technological and institutional periods. Libraries, printing, universities, scientific societies, digital databases, search engines, and AI may each alter capitalization conditions through different mechanisms.

10.11.6 Institutional Comparison

Universities, firms, public research institutes, open-source communities, independent researchers, and platform organizations provide distinct configurations for studying accumulation, circulation, control, and dependency.

10.11.7 Cross-Cultural Comparison

Concepts of knowledge, ownership, authorship, commons, education, and collective contribution vary across legal and cultural traditions. Comparative research can test the portability of the framework and reveal assumptions embedded in its current terminology.

10.11.8 Case Selection and Disconfirmation

Future empirical work should select cases capable of challenging the framework rather than merely illustrating it. Cases of high openness with declining concentration, high accumulation with broad recirculation, low-resource actors achieving rapid generative expansion, and infrastructure owners with limited epistemic control can all help refine the theory.

10.12 Extensions of the Foundational Framework

This subsection organizes the principal theoretical extensions emerging from the present paper. Its objective is to preserve continuity across the wider research programme while maintaining distinct research questions and literatures for each branch.

10.12.1 AI Political Economy

A dedicated study should develop industrialized epistemic capitalization, machine-scaled production, compute intensity, automated question-space exploration, and enclosure of generative capacity.

10.12.2 Knowledge-Commons Jurisprudence

A jurisprudential study should examine licensing, retained rights, provenance, attribution, stewardship, ownership, integrity, and remedies within specific legal systems.

10.12.3 Ethics of Knowledge-Capital Accumulation

A normative study should develop criteria for productive accumulation, appropriation, generative extraction, exploitation, recirculation, and responsibilities toward shared generative conditions.

10.12.4 Praxis under Unequal Generative Conditions

A praxis-oriented branch should examine how independent and low-capital knowledge producers can preserve, reproduce, and expand generativity under conditions of limited financial, infrastructural, and institutional resources.

10.12.5 Epistemology of AI-Mediated Knowing

An epistemological branch should examine the relation among knowledge production, direct encounter, epistemic formation, embodied knowledge, temporality, and AI mediation.

10.12.6 Philosophical Method and Record

A methodological branch should examine the role of AI-assisted dialogue in philosophical generation and the relation among chronological dialogue, analytical commentary, and stabilized academic publication.

The open problems identified in this section delimit the claims of the present paper while extending its analytical vocabulary into a wider research programme. Their diversity also reinforces the foundational character of the inquiry. Knowledge-capital expansion connects political economy, epistemology, commons governance, institutional analysis, jurisprudence, ethics, and technology while preserving distinct research questions within each domain. Section 11 concludes by summarizing the framework and its principal theoretical contribution.

11 Conclusion

This section concludes the foundational inquiry by consolidating the conceptual architecture developed throughout the paper, clarifying its principal theoretical contribution, and identifying the role of the framework within the wider research programme. The discussion proceeds from the definition of knowledge capital to the dynamics of expansion, the conditions created by public knowledge, the distinction between dynamical and relational properties, and the implications for contemporary AI-mediated epistemic production. The section then closes by restating the provisional character of the framework and the research directions that follow from it.

The central object of the paper has been knowledge-capital expansion under conditions of public knowledge. The inquiry began from a simple observation: epistemic resources can influence subsequent knowledge production through more than their immediate informational content. Propositions, questions, concepts, methods, data, tools, infrastructures, and other epistemic resources can alter the conditions under which later inquiry occurs. Previous epistemic production can thereby change the capacity for future epistemic production.

This recursive property motivates the concept of *knowledge capital*. The paper has provisionally defined knowledge capital through generative consequence: an epistemic resource functions as knowledge capital when its possession, access, or control modifies the conditions, rate, range, direction, or combinatorial possibilities of subsequent knowledge generation. The concept therefore shifts attention from the amount of knowledge presently available toward the productive consequences of epistemic resources across time.

Knowledge-capital expansion identifies the wider dynamical structure through which these generative consequences become recursive. Accumulated epistemic resources can increase future generative capacity, and that increased capacity can contribute to further epistemic accumulation. The paper has distinguished several mechanisms within this wider process, including second-order generativity, recursive capitalization, question-space expansion, cross-domain recombination, path dependence, cross-capital conversion, and feedback among epistemic, reputational, financial, network, institutional, and infrastructural resources.

Questions occupy a particularly important place within this framework. Epistemic production can expand the range of available questions in addition to producing answers. A productive question can reorganize an inquiry, identify new variables, connect previously separate literatures, create new data requirements, or open a sequence of later investigations. Knowledge-capital accumulation can therefore include expansion of the conditions under which future questions become formulable.

The analysis of public knowledge introduced a second dimension of the problem. A knowledge commons can function as shared generative infrastructure because the same epistemic resources can enter multiple subsequent productive trajectories. Public circulation can enlarge field-level possibilities of research, learning, recombination, and innovation.

The generative consequences of openness depend upon capitalization capacity. Actors encounter public knowledge through heterogeneous configurations of prior knowledge, language, time, funding, institutional position, networks, computational resources, and infrastructure. Similar formal access can therefore produce different changes in future generative capacity. The paper has described this relation through *capitalization asymmetry*.

Capitalization asymmetry creates the possibility of recursive divergence. Actors who derive greater generative gains from one round of public resources can acquire additional epistemic or complementary capital that increases their capacity to capitalize upon later resources. Public accessibility can therefore support growth in aggregate field-level generativity while differences in effective generative capacity also increase. The proposed *openness–concentration paradox* identifies this possible coexistence between wider shared accessibility and increasing concentration of practical capitalization capacity.

The paper has also argued for a strict analytical separation between the dynamics of knowledge-capital expansion and positions within relations of epistemic production. This distinction constitutes one of the principal theoretical contributions of the inquiry.

Knowledge-capital expansion is a dynamical property. It concerns trajectories, feedback, accumulation, reproduction, recombination, conversion, and changes in future generative capacity.

A knowledge capitalist is a relational position. The category concerns an actor's relation to means and conditions of epistemic production, epistemic labor, infrastructure, control, appropriation, dependency, and the organization of future productive possibilities.

The distinction allows rapid knowledge accumulation to be analyzed independently from capitalist social position. An individual researcher, cooperative, community, public institution, or open epistemic network can exhibit strong recursive accumulation while maintaining broad circulation of resulting resources. An organization can occupy a powerful position within epistemic production through control of infrastructure while the individuals exercising that control perform a limited share of the direct epistemic labor involved.

The resulting formulation can be stated concisely:

Capital-like expansion is a dynamic property; capitalist position is a relational property.

This distinction also clarifies the relation between accumulation and enclosure. Knowledge-capital accumulation can enter different governance trajectories. Accumulated capacities can become proprietary, remain broadly shared, circulate between public and private configurations, or contribute to new common generative conditions. The political-economic character of an accumulation process therefore depends upon relations of control, circulation, dependency, appropriation, and regeneration.

The paper has developed several relational categories for analyzing these differences. *Epistemic dependency* describes reliance upon generative conditions controlled elsewhere. *Epistemic subordination* describes stronger conditions in which such dependence permits another actor to govern important dimensions of epistemic production. *Generative precarity* introduces instability in access to the conditions required for sustained generation.

The concepts of appropriation, generative extraction, and generative exploitation provide a further sequence. Appropriation concerns incorporation of generated or shared value into a controllable accumulation process. Generative extraction concerns systematic flows from a source field toward an actor who disproportionately retains the resulting increase in generative capacity. Generative exploitation is reserved provisionally for stronger configurations in which extraction is accompanied by degradation, suppression, dependency, lock-in, or loss of the source's future generativity.

These distinctions preserve space for accumulation that contributes positively to shared generative conditions. An actor can capitalize extensively upon public knowledge while returning concepts, methods, data, infrastructure, teaching, funding, or other resources to the commons. The concept of *generative return* identifies this wider problem of how value generated through shared epistemic resources can contribute to reproduction of the conditions supporting future generation.

The same framework has jurisprudential implications. Ownership, possession, control, and appropriation describe different relations to epistemic resources. Priority and provenance can also be separated from proprietorship. Recognition of historical contribution, attribution, integrity, and accountability can therefore be analyzed independently from exclusive control over future conceptual use.

These distinctions motivate future work on stewardship-oriented governance, retained rights, licensing, attribution, provenance, and the legal architecture of generative commons. The foundational analysis does not prescribe a single rights regime. It instead identifies the relations that a jurisprudence of public knowledge should distinguish when evaluating circulation, protection, control, and enclosure.

Artificial intelligence makes several of these dynamics especially visible. AI can enlarge epistemic absorption capacity by increasing the amount of publicly accessible knowledge that becomes practically searchable, translatable, comparable, and recombinable within a given period. It can expand question-space exploration, increase epistemic throughput, and support machine-scaled research workflows.

AI can also strengthen the role of infrastructural epistemic capital. Models, compute, retrieval systems, data pipelines, agent infrastructures, and evaluation systems can become reusable means of future knowledge production. The practical capacity to capitalize upon public knowledge can therefore de-

pend increasingly upon access to technical infrastructures whose distribution differs substantially across actors.

This development creates a possible movement from control over completed epistemic products toward control over knowledge-generating capacity. Public knowledge can contribute to infrastructures whose future productive capabilities remain concentrated under private or institutional control. The resulting problem belongs to a wider political economy of industrialized epistemic capitalization and requires dedicated analysis beyond the present foundational paper.

The AI case also reveals an epistemological boundary of the framework. Expansion of epistemic production and formation of the knowing subject can follow different trajectories. Machine assistance can increase the quantity and speed of generated epistemic artifacts while human understanding, judgment, conceptual formation, and direct engagement with objects of inquiry develop through different temporal and relational processes.

Knowledge production therefore intersects with a broader question concerning epistemic formation. Some forms of knowledge can be rapidly codified and transferred, while others depend upon embodied practice, situated experience, sustained relations, interpretive development, or extended periods of learning. These differences establish possible limits to epistemic capitalization and motivate subsequent work on knowing in the age of AI.

The framework developed in this paper remains preliminary. Its concepts require historical comparison, philosophical refinement, empirical operationalization, and testing across different institutional settings. The boundary of knowledge capital remains open. Capitalization capacity lacks a general measure. Relations among individual, collective, institutional, and infrastructural knowledge capital require further specification. The conditions under which openness produces concentration remain an empirical question. The thresholds between appropriation, extraction, and exploitation require a dedicated normative theory. Legal arrangements require jurisdiction-specific analysis.

These limitations define the productive role of the present inquiry. The paper provides a conceptual architecture through which several previously separated questions can be examined together: how epistemic resources change future generative capacity; how those effects become recursive; how public knowledge enters private and collective accumulation; how formally shared resources can produce heterogeneous generative gains; how epistemic advantages convert into other forms of capital; how control over productive conditions creates relational positions; how accumulated capacities circulate or become enclosed; and how AI changes the scale and infrastructure of these processes.

The resulting research programme extends in several directions. A political economy of AI can examine industrialized epistemic capitalization and the concentration of generative infrastructure. A jurisprudential inquiry can develop governance structures for public knowledge, retained rights, provenance, and stewardship. A normative inquiry can examine generative extraction, exploitation, recirculation, and responsibilities toward commons. A praxis-oriented inquiry can examine the conditions under which low-capital and independent knowledge producers sustain generativity. An epistemological branch can examine knowledge production, knowing, and epistemic formation under AI mediation. Further methodological work can examine AI-assisted philosophical dialogue and the preservation of conceptual becoming.

Knowledge-capital expansion therefore provides a common analytical object across these later branches while preserving their distinct theoretical and methodological requirements. The foundational proposition of the present paper is correspondingly modest: public epistemic resources can enter recursive generative processes whose dynamics, distribution, governance, and relational organization deserve analysis as a distinct problem of contemporary knowledge production.

The public knowledge commons is consequently more than a repository of shared epistemic outputs. It is part of the generative environment from which future knowledge becomes possible. Understanding its political economy requires attention to both the expansion of epistemic capacity and the relations through which that capacity is produced, controlled, circulated, and regenerated.

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