

The upgrade of Marx's Micro-Circulation Theory in the Era of Artificial Intelligence: From Morphological Changes to Algorithmic Acceleration

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Abstract: Artificial intelligence is profoundly transforming the operational modes of the commodity circulation process; however, existing research has largely proceeded from the perspective of technological efficiency and has lacked a systematic examination from the standpoint of political economy. Drawing upon Marx's theory of the costs of circulation and the time of circulation as set forth in *Capital*, this paper decomposes the cost of circulation into its social, natural, and technical components, and constructs an updated formula under AI conditions. The study shows that AI systematically dissolves the social frictions of circulation, causing the cost of circulation to contract from “informational friction” to “physical constraint”; the driving force behind the elevation of turnover acceleration derives from the law of capital competition rather than from technological diffusion; the costs of circulation are likewise displaced from dispersed commercial labour towards concentrated platform capital, giving rise to a new form of monopolistic power assuming the form of “technological rent”; and the acceleration of circulation, while expanding the supply of commodities, simultaneously expels labour, thereby intensifying, under new conditions, the basic contradiction between production and consumption.

Keywords: Artificial Intelligence; Costs of Circulation; Time of Circulation; Turnover of Capital; Platform Monopoly

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1. Introduction

As of 2026, artificial intelligence technologies represented by large language models are penetrating, at an accelerated pace, every link of the circulation of commodities; algorithmic recommendation systems have reshaped the modes of matching supply and demand, smart contracts have compressed the cycles of transactional negotiation and credit examination, and automated logistics scheduling has transformed the organisational forms of the spatial transfer of commodities. The application of AI technology in the spheres of the supply chain and marketing is capable of saving the global commercial sector trillions of dollars in operating costs each year, and these changes are not merely improvements in efficiency at the technical level, but pertain also to a profound reorganisation of the relations of value distribution within the circulation process.

Within the field of Marxist political economy, discussion of AI has largely been concentrated upon the questions of the substitution of labour and the creation of value within the production process, while analysis of the sphere of circulation has remained comparatively weak. Looking back to Volume II of *Capital*, Marx systematically expounded the theory of the costs

of circulation and the time of circulation, pointing out that the process of circulation does not create value yet constitutes a necessary condition for the realization of surplus value, that the costs of circulation, as “unproductive but necessary expenses,” form a deduction from surplus value, and that the time of circulation, as a component of the turnover of capital, directly conditions the level of the annual rate of surplus value. This theory furnishes the basic categories and the logical structure for the analysis of the cost of circulation, yet the concrete background of its exposition was the nineteenth century, and when the algorithm has replaced the bookkeeper, the data stream has replaced the postal letter, and digital payment has replaced the counting of cash, the concrete content of these categories must be redefined, and whether their theoretical logic remains valid must likewise be examined anew.

2. Pioneering Pathways in Traditional Analyses of Circulation

2.1 The Optimism of the Classical School: Circulation Costs as Eliminable “Friction”

In the *Tableau Économique* (published in 1758), François Quesnay was the first to depict—in diagrammatic form—the panoramic circulation of society's total product^[1]; he elevated the circulation of products from a mere series of individual acts of buying and selling to a systemic component of social reproduction undertaken by the various social classes. Marx hailed this as “an idea of the most brilliant genius.” However, Quesnay's vision of circulation was, in essence, a tableau of harmonious and balanced natural order; within this framework, the various social classes engaged in exchange in accordance with “natural laws,” and circulation itself posed no obstacles and incurred no independent costs. Any disruption of circulation was regarded as the consequence of artificial interventions in violation of the natural order, rather than as an inherent characteristic of the mode of commodity production itself.

In *The Wealth of Nations* (published in 1776), Adam Smith explicitly addressed the question of the consumption of social resources by the circulation process; he characterised the expenses of maintaining monetary circulation as a form of “dead cost” to society^[2], and advocated the use of paper currency and the banking credit system to remedy the social losses occasioned by the immobilisation of capital. Yet Smith's account of the costs of circulation remained throughout at the level of technical pragmatism: the expenses required for circulation, in his view, arose from the monetary media and merchant labour involved in the physical act of exchange, and these “necessary wastes” could be economised—or even entirely eliminated—through institutional innovation.

In *A Treatise on Political Economy* (published in 1803), Jean-Baptiste Say's dictum that “supply creates its own demand” effectively dissolved, in essence, the inherent difficulty of the transformation of commodities into the money-form^[3], thereby pushing Smith's technical optimism to its logical extreme: every act of production, he held, generates an equivalent magnitude of purchasing power, and consequently the “perilous leap” of the metamorphosis of commodities simply does not exist. “Say's Law” represents the logical culmination of the Classical School's conception of circulation: circulation is regarded merely as an incidental by-product of production rather than as an independent stage, and the costs of circulation as nothing more than contingent frictions external to the commodity economy. This judgement further implies that the costs of circulation exist solely on account of the imperfection of technical means; once sufficiently advanced instruments become available, the process of circulation would no longer entail any independent costs whatsoever.

2.2 Marx's Critique: Circulation Costs as a Structural Necessity

Classical political economy reduced the costs of circulation to institutional conflicts and technical frictions, rather than treating them as manifestations of the structural contradictions inherent in the commodity economy itself; it held that the costs of circulation could, in principle, be entirely eliminated through technological progress. As a consequence, it lacked any unified theory capable of accounting for the phenomenon of value-form transformation that takes place within the process of circulation. Marx did not deny the Classical School's view that technological progress can economise on the costs of circulation; rather, he advanced, at a deeper analytical level, a central thesis of his own: the ground for the existence of the costs of circulation lies not in the imperfection of technical conditions, but in the social form of the commodity economy itself.

In a traditional commodity economy, production is carried on privately, yet products must secure social recognition by way of the market; this means that commodities must undergo a “metamorphosis” from the commodity-form into the money-

form. Such transformation constitutes an independent stage of the process, within which the metamorphosis is conditioned by factors such as private labour, social labour, and use-value, and which therefore necessarily requires an independent expenditure of time and necessarily incurs independent costs. From this there follows a conclusion diametrically opposed to that of the Classical School: the costs of circulation are greater than zero (so long as the commodity economy exists).

In Volume II of *Capital*, Marx translated this judgement into a concrete categorical analysis: he systematically delimited the two major categories of “circulation time” and “circulation costs,” and further subdivided the costs of circulation into three types—pure costs of circulation, storage costs, and transport costs. The ground for the existence of the pure costs of circulation is located in the “social form” of the commodity economy, whereas the ground for the existence of storage costs and transport costs is located in the “physical determinateness” of the commodity. Although these two grounds are qualitatively distinct in nature, they are nevertheless unified under the single concept of “costs of circulation.”

2.3 The Necessity of Constructing a Model of Circulation Costs for the AI Era

The Classical School conceived the costs of circulation as residual frictions arising from the as-yet imperfect organization of the market—frictions destined to be eliminated through the deepening of the division of labour, the refinement of instruments, and the perfecting of institutions; this judgement furnished the initial theoretical impetus for the analysis of circulation costs: inasmuch as these costs constitute a pure deduction from social wealth, the search for paths to their elimination emerged as a legitimate task of political economy.

Marx, for his part, carried this task to a still deeper level: he demonstrated that the costs of circulation arise not merely from the “imperfection” of the market, but are rooted in a structural necessity inherent in the very form of the commodity economy itself: so long as products exist in the form of commodities, the process of metamorphosis must inevitably consume time, labour, and material resources. The costs of circulation are therefore not transient obstacles awaiting elimination, but objective costs that coexist with the commodity economy itself: factors that are “structurally irreducible.”

The theoretical bedrock of the analysis of circulation costs derives from the judgement that such costs are “structurally irreducible”; yet whether this “irreducibility” refers to all components of the costs of circulation, or only to certain specific components, has never been further elucidated—a question that the rapid advance of AI technology has now forced into the open. The selective operation of AI technology has driven the internal heterogeneity of the costs of circulation from latency into manifest form, thereby rendering it possible to accomplish, through the construction of a model of circulation costs for the AI era, those internal distinctions that Marx himself never explicitly drew.

3. The Formalization (Modelling) of Marx's Theory of Circulation Costs

3.1 The Basic Structure of the Circulation Cost Model: The Metamorphosis of Commodities

Before constructing a model for the AI era, it is necessary first to render Marx's theory of circulation costs as a formalised structure amenable to decomposition. In Volume II of *Capital*, taking the “metamorphosis” of commodity circulation as its core, Marx represents the circuit of capital as $G-W \cdots P \cdots W'-G'$, in which $(G-W)$ denotes the transformation of money capital into the elements of productive capital, and $(W'-G')$ denotes the transformation of commodity capital into money capital^[4]; for capital to accomplish its self-expansion, it must pass through these changes of value-form, and since no metamorphosis can be accomplished without cost—and since every metamorphosis is fraught with uncertainty—the metamorphosis is a “perilous leap” (*salto mortale*)^[5].

Within the circuit of capital, the process of production can be planned by the capitalist with relative precision, yet the successful transformation of the value-form does not depend on the will of the capitalist; the metamorphosis of value-form is a process of circulation in the strict sense, and the presence of competitors and the uncertainty of purchasers within this process of circulation render an expenditure of value in the course of metamorphosis unavoidable, so that, in order to complete one full cycle of metamorphosis, capital must bear additional circulation costs. The proposition that “circulation costs are the necessary costs of the metamorphosis” thus constitutes the theoretical point of departure for the work of formalization.

On the basis of this theoretical point of departure for formalization, the circulation process of capital may be conceived as consisting of two metamorphoses: the first is the act of selling ($W' \rightarrow G'$), in which value is transformed from the commodity-

form into the money-form, with the corresponding circulation cost defined as c_1 ; the second is the act of buying ($G \rightarrow W$), in which the money-form is transformed into the commodity-form, with the corresponding circulation cost defined as c_2 ; the total cost of the entire circulation process is therefore $c_1 + c_2$. Letting W denote the total magnitude of value borne by capital in completing the whole of circulation, and W' denote the magnitude of value already congealed in the commodity during the production process, we obtain: $W = W' + c_1 + c_2$. The two mechanisms of deduction of distinct character that Marx differentiates in his exposition of the circulation process furnish the theoretical foundation for the decomposition of c_i : the one being the loss of the capacity for value-expansion along the temporal dimension, the other being the direct consumption of resources along the resource dimension.

3.2 The Internal Structure of the Circulation Cost Model: Time of Circulation and Costs of Circulation

The metamorphosis of commodity capital within the sphere of circulation is not accomplished instantaneously; every change of form requires a “time of circulation,” that is, the duration during which capital, whether in the commodity-form or the money-form, remains within the sphere of circulation. The time of circulation expended in the selling phase is t_1 , and that expended in the buying phase is t_2 , so that the total time of circulation for the whole process is $t_1 + t_2$. The “time of circulation” creates no value, but is merely a “deduction” from the time during which capital participates in the production process, and Marx's assessment of “time of circulation” is accordingly negative^[6]. In each phase of the transformation of the commodity's value-form, the process is constrained by objective factors such as market conditions and spatial distance, so that instantaneous transformation is impossible; let p denote the capacity for value-expansion lost over the entire process, then the time-cost of the selling phase is $t_1 \times p$ and that of the buying phase is $t_2 \times p$, and hence $t_1 > 0$ and $t_2 > 0$ constitute the norm in reality.

During the period of transport from the place of production to the place of sale, the commodity exists in the state of potential commodity capital; during the period in which it is displayed in the market awaiting a buyer, the commodity exists in the state of as-yet-unrealized commodity capital; and during the period of contract signing and payment settlement, the commodity exists in the state of formal transformation. Each of these phases of circulation is subject to distinct objective conditions: some depend on spatial distance and the means of transport, others on the degree of dispersion of market information and the complexity of trading institutions; yet Marx subsumes them all together under the category of “time of circulation,” constituting a temporal deduction from capital's capacity for self-expansion.

The metamorphosis of commodity capital within the sphere of circulation requires the consumption of resources, and every change of form entails “costs of circulation,” that is, the resources expended in bookkeeping and in the receipt and payment of money. The pure costs of circulation in the selling phase are denoted k_1 , and those in the buying phase k_2 , so that the total costs of circulation for the whole process amount to $k_1 + k_2$. Costs of circulation create no value, but are unproductive outlays deducted from surplus-value, and Marx regards “costs of circulation” as expenditures incurred purely for the realization of the metamorphosis. Under frictionless conditions, the completion of the metamorphosis would yield $k_1 + k_2 = 0$; but in reality the metamorphosis always requires the transmission and recording of information, so that the costs of circulation are unavoidably positive. Nevertheless, the development of commercial institutions and the advance of technical means tend to drive down the costs of circulation apportioned per unit commodity, and $k_1 + k_2 \rightarrow 0$ constitutes a historical tendency.

The downward tendency of the costs of circulation is not uniformly distributed, but operates upon particular types of circulation costs; it is therefore possible to subject the costs of circulation to a systematic classification. The pure costs of circulation neither alter the material form of the commodity nor augment its use-value, and therefore create no value; the costs of transport and storage do not alter the material form of the commodity but do alter its spatial position, and the labour of transport creates value. This classification discloses an underlying theoretical logic: whatever costs are rooted in the “social form” are, in essence, the costs of information processing and social coordination, and can be supplanted by more efficient technologies of information processing; whereas whatever costs are rooted in the “physical determinateness” are, in essence, the costs of overcoming the objective constraints of the material world, in the face of which information technology is powerless. In Marx's own era, this logic remained a merely taxonomic distinction, not yet manifested as an empirically observable evolutionary divergence.

3.3 The Complete Expression of the Metamorphosis

On the basis of the foregoing comprehensive analysis of the metamorphosis, it can be seen that the circulation process of capital consists of two metamorphoses, each of which consumes time of circulation and costs of circulation, yielding the complete formalized expression of the theory of circulation costs: $W=W'+(k_1+t_1 \times p)+(k_2+t_2 \times p)$; and since the total value burden borne by capital in completing one full cycle equals the value congealed in the commodity during production plus the total circulation costs, $W=W'+C$, the total circulation costs are accordingly: $C=(k_1+t_1 \times p)+(k_2+t_2 \times p)$.

Within the total circulation cost $C=(k_1+t_1 \times p)+(k_2+t_2 \times p)$, the circulation costs are composed of direct outlays and time-costs; the aggregate direct outlays k_1+k_2 represent the direct consumption of resources, borne through the expenditure of material means and labour; the aggregate time-costs $(t_1+t_2) \times p$ represent the indirect loss of opportunities for self-expansion, borne through the time during which capital is bound up in the non-productive sphere; k_i is the value “consumed in outlay,” while $t_i \times p$ is the value “not created”; even if technology were to compress direct outlays to zero ($k \rightarrow 0$), so long as the time of circulation still subsists ($t > 0$), the circulation costs cannot possibly vanish^[7].

In the era of the traditional economy, the selling phase and the buying phase each possessed their own distinct scales of outlay and time consumption, and could not be conflated into a single undifferentiated “cost of circulation”; nor had technology yet differentiated the internal structure of circulation costs, so that as long as capital possessed the capacity for self-expansion, k_i and t_i sufficed to account for the circulation costs, and $C > 0$ constituted a structural feature of the commodity economy^[8]; circulation costs could be continually compressed by technological progress but could never be wholly eliminated, and the uncertainty inherent in the metamorphosis could be mitigated but never eradicated. In the era of the AI economy, however, technology exerts radically different effects upon the internal constituents of k_i and t_i : the existence of algorithmic recommendation has drastically compressed the time of circulation in the selling phase and, to a certain extent, eliminated the costs of circulation in the buying phase; a further structural decomposition thus becomes the indispensable basis for the explanation of circulation costs.

4. The Upgrading of Marx's Circulation Costs in the Age of Artificial Intelligence

The emergence of AI technology has accelerated the structural decomposition and interpretation of circulation costs, rendering the internal differentiation of k_i and t_i a theoretically unavoidable object of inquiry. In the selling phase, the time required for information matching has been compressed from days to seconds, while the time required for physical transport remains unchanged; in the buying phase, the costs of bookkeeping and payment approach zero, while the costs of warehousing and packaging remain unaffected; the selective operation of technology has thus produced an observable internal differentiation: k_i and t_i contain heterogeneous components whose responses to technology are fundamentally distinct, and this internal differentiation has not been created by AI but has all along been latent within Marx's theory of circulation costs.

4.1 The Reconstitution of the Time of Circulation

In his account of the time of circulation, Marx distinguished between “buying and selling time” and “transport time”: delays in buying and selling time arise from the mutual opacity of market participants, with the reciprocal searching and repeated negotiation between buyers and sellers constituting an identifiable form of delay; delays in transport time, by contrast, arise from the objective process of physical displacement, since even after buyers and sellers have reached an agreement the commodity must still be moved through space; under traditional economic conditions, the temporal delays of searching, bargaining, transport and other such stages were collectively subsumed under t_i , and technology had not yet produced any observable evolutionary divergence among them; but under the conditions of the AI economy, the time consumed by searching and matching has been compressed by algorithms to approach zero, while the time consumed by physical transport remains unaffected by technology. Accordingly, t_i admits of a binary decomposition: $t_i = t_i^s + t_i^n$.

The social time of circulation t_i^s refers to the time consumed on account of the social obstacles to market exchange, originating in the informational opacity of the commodity economy, and is specifically described in Marx's exposition of the time of circulation: searching and bargaining time, in which the producer must seek out suitable buyers, the buyer must compare the prices and qualities offered by different sellers, and both parties must engage in repeated negotiation before a transaction can be concluded, the root of this time consumption lying in the dispersion and asymmetry of market information; and verification

and confirmation time, in which financial intermediaries must verify the authenticity of transactions and carry out risk examination, while the parties to the transaction must verify the quality of the commodity and the identity of the counterparty, such stages being measured under traditional conditions in units of “working days” and constituting a conspicuous retardation of the circulation process. Both forms of this circulation time can be compressed to zero under conditions of informational completeness and established trust.

The natural time of circulation t_i^n refers to the time consumed on account of the physical displacement of the commodity, originating in the objective constraints of the material world, and is specifically described in Marx's exposition of the time of circulation: spatial displacement and physical handling time, in which the commodity must undergo a series of physical operations such as transport and loading and unloading in being conveyed from the place of production to the place of consumption, the duration of which depends on the physical distance between the two points and on the operating speed of the means of transport, and which under current technological conditions has already approached a relatively stable physical limit^[9]; and natural process and natural interruption time, in which certain commodities must undergo specific physical or chemical processes before attaining their finished form, and in which transport is directly constrained by natural conditions, such time consumption possessing an irreducible natural basis that can be circumvented by no information technology whatever. Both forms of this circulation time persist even when market information is fully transparent and contracts have been duly concluded.

4.2 The Reconstitution of the Costs of Circulation

In his account of the costs of circulation, Marx distinguished between “pure costs of circulation” and “costs of storage and transport”: pure costs of circulation arise from the social form of the commodity economy, in which value must be expressed as price and exchange must be consummated through buying and selling, such costs losing all reason in a society in which commodity exchange does not exist; the costs of storage and transport, by contrast, arise from the material mode of existence of the commodity, and so long as material products must be displaced in space and preserved in physical integrity over time, such costs cannot possibly disappear. Under traditional economic conditions, bookkeeping costs, warehousing costs and the like were collectively subsumed under k_i , and technology had not yet produced any observable evolutionary divergence among them; but under the conditions of the AI economy, bookkeeping costs and the costs of monetary receipts and payments have been compressed by algorithms to approach zero, while warehousing costs and transport costs remain unaffected by technology. Accordingly, k_i admits of a binary decomposition: $k_i = k_i^s + k_i^n$.

The social costs of circulation k_i^s refer to the costs incurred on account of the social mode of organization of the commodity economy, which would lose all reason in a society in which commodity exchange does not exist, and which are specifically described in Marx's exposition of the pure costs of circulation: bookkeeping and monetary receipt-and-payment costs, which arise from the complexity of the commodity-exchange relation and require an extensive system of accounts for recording exchange prices, receivables, and the distribution of profits; and matching and credit-management costs, which encompass the matching expenditures of searching, negotiation and contracting, together with outlays on the credit assessment of counterparties and the management of default risk, and which in essence represent the price paid by market participants in order to overcome the dispersion of information and mutual distrust.

The natural costs of circulation k_i^n refer to the expenses arising from the material form of existence of commodities. As long as material products must be displaced in space and must preserve their physical integrity over time, such costs cannot disappear. This is specifically described in Marx's discussion of storage costs and transportation costs: storage and packaging costs arise because commodities, insofar as they exist in material form, need to be stored and protected. Storage costs depend on the physical properties of the commodity, while packaging costs serve to protect the commodity's material integrity during circulation; both are rooted in the commodity's physical nature. Transportation costs arise because the use value of a commodity can be realized only when it is transported to the place where it is needed. Spatial displacement is an unavoidable material process, and the resulting expenditures, such as fuel and wear-and-tear costs, therefore have an irreducible physical basis.

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