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HISTORICAL MATERIALISM (2026) 1–37

historical materialism:
research in marxist critical theory
brill.com/hima

Vectors for Workers: Models of Automation and Autonomy in the Long AI Century

Deutscher Memorial Prize Lecture, XXII Historical Materialism Conference, 7 November 2025, SOAS University of London

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Received 11 June 2026 | Accepted 13 October 2026 |
Published online

Abstract

The rise of AI should be read not as a neutral technological advance but as the latest stage in the long struggle between capital's drive towards automation, labour's resistance to exploitation, and society's quest of autonomy. To situate AI within this history, existing theories of automation must be revisited and expanded. A theory of automation is not a study of technology's 'impact' on society, but rather a causal model explaining how automation develops and why it takes one form rather than another. Theories of automation can be divided into four categories: value theories, labour theories, metric theories, and standpoint theories. Despite extensive literature, an organic theory capable of addressing AI as part of ~~long economy cycles,~~ seeing together its microeconomic and macroeconomic dynamics, is still lacking.

Keywords

automation – artificial intelligence – labour process theory – standpoint theory – value form theory – long wave theory

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Published with license by Koninklijke Brill BV | DOI:10.1163/1569206X-BJA10139
© MATTEO PASQUINELLI, 2026 | ISSN: 1465-4466 (print) 1569-206X (online)

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In memoriam Paolo Virno (~~*27 June*~~ *1952–7 November 2025*)

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> The division of labour under the system of manufacture not only simplifies and multiplies the qualitatively different parts of society's collective worker, but also creates a fixed mathematical relation or ratio which regulates the quantitative extent of those parts – i.e. the relative number of workers, or the relative size of the group of workers, for each special function. Thus alongside the qualitative articulation, the division of labour develops a quantitative rule and a proportionality for the social labour process.
>
> KARL MARX[1]

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> Information, like land or capital, becomes a form of property monopolized by a class, a class of vectoralists, so named because they control the vectors along which information is abstracted, just as capitalists control the material means with which goods are produced, and pastoralists the land with which food is produced. This information, once the collective property of the productive classes – the working and farming classes considered together – becomes the property of yet another appropriating class.
>
> MCKENZIE WARK[2]

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Introduction

The rise of AI should not be read as a neutral technological advance but as the latest stage in the long struggle between capital's drive towards automation,

1 Marx 1981, p. 465.
2 Wark 2004, p. 29.

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labour's resistance to exploitation, and society's quest of autonomy.[3] To situate AI within this history, existing theories of automation must be revisited and expanded in a global perspective. A theory of automation is not a study of technology's *impact* on society, but rather a causal model explaining how automation develops and why it takes one form rather than another. Certainly, in the tradition of historical materialism the question concerning technology inherits past unresolved controversies and points of view. In the nineteenth century, philosophers debated automation through Hegel's notion of abstract labour, which Marx deeply criticised. Hegel saw the machine as a materialisation of workers' abstract labour, that is the abstraction of the division of labour, while Marx saw the machine as a materialisation of capital's abstract labour, that is the abstraction of value. Adam Smith's analysis of the division of labour influenced Hegel's idea, while it has been forgotten that Marx engaged with Charles Babbage's principles of labour calculation and automation. All these references remain useful to illuminate the role of technology in the capital-labour nexus, but a schism took place: at least in Western critical theory, theories of automation based on the labour form have been opposed to those based on the value form. Where to start bridging this schism in the theory of automation?

Concerning the predicament of Western capitalism, a consensus can be found around the following theory of automation: technological development is simultaneously driven by an economy of profit (selling more and more expensive commodities), time (making things faster), space (organising things in less space), energy and resources (making things cheaper), and particularly labour (paying workers less). The labour component, that is part of a broader social antagonism, is key. The way in which workers are measured and remunerated, and whether or not they resist measure and remuneration, crucially affects technological innovation. History teaches that automation is introduced where labour resistance is stronger and labour cost high, yet other factors play a role. In other historical and political contexts, the theory of automation might take other forms and be investigated according to other value systems, worldviews, and even cosmologies. In a non-capitalist mode of production for instance, automation could be shaped by an economy of equity (paying workers fairly), prosperity (producing necessary and useful goods),

3 This essay considers the terms mechanisation, automation, automatic control and automatisation as conceptually homologous and stresses the originary common social abstraction that shapes them. Automation was introduced by Delmar S. Harder, vice president of Ford, in 1948. Friedrich Pollock (1956) distinguished automation from mechanisation according to the increasing role of information in the control process.

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and sustainability (minimising the consumption of space, time and resources). One must consider that any automation theory is a space of political intervention: it is not only descriptive but also prescriptive and it can be employed to shape the design of technology to come. This initial caveat is necessary to acknowledge that any history and philosophy of technology, like the one following, is always an exercise of political synthesis.

For presentation purposes, theories of automation can be divided into four categories: standpoint theories, labour theories, metric theories, and value theories. In short: standpoint theories stress the role of social antagonism in the adoption of automation; labour theories highlight the role of the division of labour in the design of automation; metric theories see automation as a form of measure and calculation; value theories explain automation within an economic process and usually remain agnostic to its design. All these positions are entangled and dialectical, however, despite extensive literature, an organic theory capable of addressing AI as part of ~~long economy cycles,~~ seeing together its microeconomic and macroeconomic dynamics, is still lacking. In the book *The Eye of the Master: A Social History of Artificial Intelligence* I focused mostly on the labour theory of automation as a lens to read AI.[4] This essay will attempt to integrate other theories with the commitment to sketch an *organic theory of automation* in the long century of AI, that is an epoch of knowledge automation that started at least with the labour automation of the industrial age.[5]

The presentation of the problem of automation in this way and the project itself of an organic theory, however, takes inspiration from part IV of *Capital* volume one, where Marx frames machinery as a means for the production of relative surplus-value. Marx provides a systematic theory of automation that has been often overlooked. He descends from the dynamics of capital into the ramifications of the cooperation of labour and its measure, and then, into the organisation of industrial machines and large factories, ending with the recognition of working class's resistance against capitalist machines. Along this journey, one can detect how a value theory of automation is related to a metric theory of automation, which is itself imbricated into a labour theory of automation that culminates with an antagonistic or standpoint theory of automation.

4 Pasquinelli 2023.

5 For reasons of space, this essay does not treat theories that see the state as a driver of technological innovation. As is known, bureaucracy played a key role in the development of statistics (Foucault 2009, Hacking 2015) and information retrieval (Agar 2003, Wiggins and Jones 2023). The army in particular is often considered a key driver of innovation, although some scholars claim that war only accelerates existing technologies rather than inventing new ones (see Kittler 2021).

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Yet, this itinerary can be read backwards to reveal its implicit political trajectory and to stress, once again, how each component is organically part of the previous one. Starting from the end, Marx presents a standpoint theory of automation (section 15.5 on 'The Struggle between Worker and the Machine'), which is presented as part of a labour theory of automation (chapters 14 and 15 on 'Machinery and Large Scale Industry'), which is itself cast within a value theory of automation (chapter 12 on 'The Concept of Relative Surplus Value'). Thus, while in part IV of *Capital* the economic analysis begins with capital, the political synthesis begins with the antagonism of labour. It is for this pursuit of a political synthesis, which would be valid also for the age of AI automation, that this exposition of the problem of automation follows the reverse order of Marx's exposition: standpoint theories, labour theories, metric theories, and value theories of automation.

This exposition proceeds in three parts. Part I surveys the theories of automation that have consolidated since the industrial and colonial age, presenting them in this order: standpoint theories, labour theories, metric theories, and value theories. Part II illustrates current AI according to this framework in which microwork, social patterns, psychometrics, and eigencapital are identified respectively as the dimension of standpoint, labour, metrics, and value in AI. Part III reads AI through Marx's formula of the organic composition of capital and Ernest Mandel's revision of long wave theory. It concludes ~~taking~~ the issue of model collapse not just as a technical one but as a political prism of the crisis of the present and possible decline of the social order of AI.

1 Theories of Automation since the Industrial and Colonial Age

1.1 *Standpoint Theories of Automation*

Standpoint theories of automation see the design of automation as driven by social antagonism and conflicts related to hierarchies of class, gender, and race. They see technology as emerging from processes of subjectification that are simultaneously processes of refusal, resistance, but also reappropriation (sometimes involving a certain degree of psychological identification: see the position of hacker subcultures and cyborg philosophies). Standpoint theories of automation stress the effect of labour resistance and unionisation on investments in automation, and in this vein they include the impact of migrations on the investments in automation.[6] The formulation of standpoint theory

6 Mezzadra 2011.

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comes, as well known, from feminist studies, where it emphasises subjectivity as an active and antagonistic force in knowledge production.[7] These theories can be defined, in different ways, as social and sociological theories, as they focus on the role of political subjects rather than economic structures. They could be rendered as biopolitical theories too, following the way some scholars, after Foucault, have studied the production of subjectivities by technical apparatuses.[8]

Marx famously stated that machinery 'is the most powerful weapon for suppressing strikes' and that 'it would be possible to write a whole history of the inventions made since 1830 for the sole purpose of providing capital with weapons against working-class revolt.'[9] Already in nineteenth-century England, the machine was a locus of social struggle, as Maxine Berg reminded us in her book on the Machinery Question.[10] This was not a retrograde and anti-modernist struggle. Historians such as Eric Hobsbawm and E.P. Thompson have rescued the movements of machine breakers such as Luddism from the accusation of technophobia and shown their role in a novel class composition.[11] In the twentieth century, Italian *operaismo* initiated a different critique of technology in production addressing its supposed neutrality and recognising the *forces of production* as a crystallisation of the *relations of production*.[12] In addition, *operaismo* proposed to see workers' struggles as a primary and not secondary actor in capitalist innovation. In the journal *Classe Operaia*, Mario Tronti famously advanced a Copernican turn in class theory: it is class struggle which propels capitalist (and technological) development, not the other way around.[13]

7 Harding 1986; Gurung 2020.

8 Foucault 1988.

9 Marx 1981, pp. 552–3.

10 Berg 1980, p. 10. 'The very technology at the basis of economy and society was a platform of challenge and struggle. The machine was debated at length in all sectors of society. It provoked the village cleric as much as it did the cosmopolitan intellectual; it concerned the politician as much as the workman and employer; the social reformer as much as scientist and inventor.'

11 Thompson 1963; Hobsbawm 1952.

12 Panzieri 1961.

13 Tronti 1964, 1966/2019, p. 65. 'We too saw capitalist development first and the workers second. This is a mistake. Now we have to turn the problem on its head, change orientation, and start again from first principles, which means focusing on the struggle of the working class. At the level of socially developed capital, capitalist development is subordinate to working-class struggles; not only does it come after them, but it must make the political mechanism of capitalist production respond to them.'

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As part of this political and theoretical lineage, more recently Antonio Negri and Michael Hardt have pushed forward this argumentation advocating, as in Marx's original program, the appropriation of the means of production in the information economy; they also consider that, especially in information technology, the border between human and machine is difficult to trace.[14] Autonomist feminists such as Silvia Federici[15] have contested such an optimistic view and see emancipation only outside the sphere of technology, moving from the observation that, historically, domestic and care labour has been barely automated. Along similar lines, authors from Ruth Schwartz Cowan to Astra Taylor have extended the sphere of automation to include domestic and reproductive work. They reveal that where automation took place, it made women work more, not less.[16] On the other hand, a different feminist camp, that include Shulamith Firestone and Donna Haraway among others, have advocated for women's emancipation through a reappropriation of technology and even identification with it (see the cyborg figure).[17] The identification with technology becomes a controversial strategy, when it does not reveals implicit and invisibilised relations of production. Recently, Neda Atanasoski and Kalindi Vora have shown how the dreams of full automation (which include AI) are grounded on the 'surrogate humanity' of enslaved, servants, proletarians, and women, that make possible through their forced or invisibilised labour the universalistic ideal of the autonomous (often white and western) subject.[18]

1.2 *Labour Theories of Automation*

Labour theories of automation explain its development from the perspective of the material logic of production and the division of labour, or labour process, rather than the standpoint of subjectivities. In the eighteenth century, Adam Smith was the first to sketch a labour theory of automation in *The Wealth of Nations* by recognising that machines are invented mostly by imitating the

14 Negri 2018, Hardt and Negri 2017, pp. 106, 109. 'Instead of rejecting technology, then, we must start from within the technological and biopolitical fabric of our lives and chart from there a path of liberation. … Our intellectual and corporeal development are inseparable from the creation of machines internal and external to our minds and bodies. Machines constitute and are constituted by human reality.'

15 Federici 2019.

16 Cowan 1983; Taylor 2019.

17 Firestone 1970; Haraway 1985.

18 Atanasoski and Vora 2019; see also Gray and Suri 2019; Benjamin 2019; Munn 2022.

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organisation of tasks in the workplace.[19] Hegel's notion of abstract labour, as labour that gives form to machinery as well as society and its institutions, was partially indebted to Adam Smith, who Hegel commented on already in his Jena lectures in the early nineteenth century.[20] However, it fell to Babbage to systematise Adam Smith's insight in a consistent labour theory of automation, that he presented in his 1832 popular manual of management *On the Economy of Machinery and Manufactures*.[21]

Marx adopted the labour theory of automation in part IV of *Capital* but he had already discussed it in the *Grundrisse*, where he stressed that the road to technological innovation usually is not the analysis of scientific laws and their subsequent application to production but the analysis of the division of labour.[22] The spontaneous intelligence of the cooperation of labour, rather than science, gives form to automation. When Babbage wrote that 'the division of labour suggests the contrivance of tools and machinery to execute its processes', it meant that the design of the division of labour shapes the inner design of technology. Babbage complemented this theory with the principle of labour calculation (that Braverman termed the 'Babbage principle')[23] to indicate that the division of labour allows another key function: the precise computation of the costs of labour and resources.[24]

According to the Babbage principle, the division of labour is an instrument of measurement and implicit metric of labour, dividing the workforce in classes of skill and therefore salary. Babbage's vision of management had a clear disciplinary nature, that Meredith Whittaker, James Muldoon and Boxi Wu trace

19 Smith 1776, 'The invention of all those machines by which labour is so much facilitated and abridged seems to have been originally owing to the division of labour.'

20 Hegel 1805.

21 Babbage 1832, pp. 131–6. 'Perhaps the most important principle on which the economy of a manufacturer depends, is the *division of labour* amongst the persons who perform the work. … The division of labour suggests the contrivance of tools and machinery to execute its processes. … When each process has been reduced to the use of some simple tool, the union of all these tools, actuated by one moving power, constitutes a machine.'

22 Marx 1973, p. 704, translation modified. 'This road is, rather, analysis [*Analyse*] – through the division of labour, which gradually transforms the workers' operations into more and more mechanical ones, so that at a certain point a mechanism can step into their places.'

23 Braverman 1974.

24 Babbage 1832, p. 137. 'The master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill and force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.'

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back to the discipline of enslaved workers in the colonial plantations.[25] Many scholars have stressed the similarity between surveillance and discipline in the plantations and techniques to measure and organise labour in the industrial factories.[26] Silvia Federici predates this phenomenon to early modernity: she argues that the rise of modern rationality and a mechanical worldview was related to the transformation of women's bodies and the collective body into a docile and productive machine.[27] In Federici's view, social relations became abstract machines before the regime of industrial capitalism turned them into actual machines.

The labour theory of automation can be easily extended from manual to mental labour, involving more abstract domains such as knowledge, information and calculus. The labour theory of automation inspired the early projects of computation. Babbage maintained the two principles of the division of labour in his project for the automation of mental labour that resulted in the Difference Engine, the first prototype of the modern automated computer.[28] Babbage was inspired by the French mathematician Gaspard de Prony who first had the idea of applying Adam Smith's principle of the division of labour to hand calculation of logarithmic tables. Babbage took De Prony's algorithm, known also as 'method of difference', and sought to embody it into the mechanism of the Difference Engine. In synthesis, automated computation was not born out of pure mathematics, but by applying the principle of the division of labour to mental labour.

Babbage's intuition was later revived by pioneers of computation such as Turing and also Simon and Newell, who openly acknowledged the influence of labour management on Operation Research and AI.[29] The most acute reader of Babbage's theory of the division of labour in the twentieth century remains Harry Braverman, whose influential 1974 book *Labour and Monopoly Capital* initiated the labour process and deskilling debate.[30] Braverman rediscovered and named the 'Babbage principle'[31] and brought attention to the relation between his experiments in computation and political economy, influencing later scholars in the history of science.[32] Braverman extended his critique of Babbage to the Taylorism of the twentieth century and highlighted how

25 Whittaker 2023; Muldoon and Wu 2023. See also Paci 2025.
26 Adas 1989; Mirzoeff 2011; Browne 2015; Fiori 2020.
27 Federici 2004.
28 Daston 2018.
29 Turing 1950; Simon and Newell 1958; see also Daston et al. 2015, p. 42.
30 Smith 2015.
31 Foster 2024.
32 Daston 1994 and 2018; Schaffer 1994.

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scientific management constituted a technique of knowledge extraction and alienation. He identified three principles of Taylorism: 1) the dissociation of the labour process from the skills of the workers; 2) the separation of conception from execution; 3) the use of the monopoly over knowledge to control each step of the labour process.[33] Criticising these principles, Braverman aimed at recognising the role of cooperative labour and the spontaneous intelligence of workers also in the development of innovation and scientific abstractions. With a perspective close to historical epistemology of science,[34] Braverman argued that science did not help automation, rather labour organisation did. Against the myth about the role of science in industry, Braverman brought the canonical example of the steam engine, which prompted the development of the science of thermodynamics rather than the other way around.[35]

A decade earlier, in the debates of Italian *operaismo*, Romano Alquati made a similar critique of scientific management and went to recognise *information* as a key element of its operations, and importantly as something that workers themselves produce. During his militant co-research ('*conricerca*') at Olivetti, one of the first computer factories in the world, Alquati distinguished two flows of information in the production processes: control information and valorising information.[36] The former is the information appropriated by industrial and bureaucratic apparatuses to control production, the latter is the information produced by workers through the continuous micro-decisions and measurements that give shape and value to the final product.[37] Aside from these two types of operative information, Alquati also distinguished information crystallised in bureaucratic apparatuses and archives (such as in databases) and

33 1) 'The managers assume … the burden of gathering together all of the traditional knowledge which in the past has been possessed by the workmen and then of classifying, tabulating, and reducing this knowledge to rules, laws, and formulae' (Taylor 1911, p. 36). 2) 'All possible brain work should be removed from the shop and centered in the planning or laying-out department' (Taylor 1903: p. 98). 3) 'Perhaps the most prominent single element in modern scientific management is the task idea. The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work' (Taylor 1911: p. 39).

34 See Hessen 1931.

35 Braverman 1974, p. 155.

36 Pasquinelli 2015.

37 Alquati 1963, p. 121, own translation. 'Information is essential to the labour force, it is what the worker – by means of constant capital – transmits to the means of production on the basis of evaluations, measurements, and elaborations in order to effect on the object of work all those changes of form that give it the required use value.'

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information objectified in methods, techniques and machines.[38] This kind of information that is formalised in techniques and embodied in databases has constituted the repository of codified knowledge that made possible the rise of AI in the following stage of automation.

1.3 *Metric Theories of Automation*

The Babbage principle sees the division of labour as a structure of relations to be organised but also a means to measure labour: the division of labour becomes an instrument of measurement and computation. An optimal disposition of tasks is an implicit measure of each task in terms of wage, time, energy and resources that are required for production. It should be repeated that measures are part of long political negotiations and economic dynamics[39] and one can easily envision such negotiations in the forming and adoption of new machines. The clock appears as one of the first metrics of labour in the industrial age and the discipline it implemented sparked resistance. The clock can be seen as the first social machine of modernity. Yet as Moshe Postone noted, it was the new (and more abstract) temporal organisation of production and circulation in fourteenth-century Europe that required more exact clocks, not the other way around.[40] More efficient clockwork mechanisms emerged from the need to measure labour in a more 'abstract', precise, way.

Other technologies of the industrial age such as steam engine and telegraph can be seen under this metric perspective. Norton Wise has proposed seeing both the steam engine and telegraph as 'mediating machines', as epistemic mediators between political economy and natural philosophy, between labour and science. The steam engine played a twofold role in the measurement of labour and the consolidation of the metric unit of work in physics.[41] In a similar way the telegraph imposed the first quantification of communication and encoding of language into a binary code.[42] This insight points to a common ground between value and labour in theories of automation: one according to which technology is not only a means of production but also an instrument for measuring production and its value. This perspective can be identified as a metric theory of automation, according to which techniques that are used to measure labour suggest also the design of new technologies of automation.

38 Alquati 1975, p. 130.
39 Kula 1986.
40 Postone 1993, p. 212.
41 Wise 1988, p. 77.
42 Pasquinelli 2022.

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One can describe the historical process of technological development from the perspective of measure in this way: first, the division of labour becomes implicitly or explicitly an instrument to measure labour; second, new practices of measurement prompt the rise of new metrics, instruments of measurement, and metrology as a discipline; third, new instruments of measurement influence in their own the design of new techniques of automation; fourth, a new technology engenders a new configuration of space, time, and social relations, and implicitly projects new metrics of such dimensions upon the social body. In these dynamics one should acknowledge that workers' resistance affects the division of labour and its measure, influencing therefore also the design of automation that emerges in this process. The metric theory of automation, then, can be used as a prism to pursue a further integration of labour theories, social theories, and value theories of automation.

1.4 *Value Theories of Automation*

Value theories of automation explain automation as a process that capitalism steers from the outside, selecting those technologies that improve production and circulation. In *Capital and Automation*, Ramin Ramtin found that 'although the literature on automation is certainly extensive, there is a clear gap in that which deals with the issue of automation from the perspective of a Marxian value theory.'[43] According to Ramtin, technology has to be understood from the point of view of the value form that capital impresses on it as a seal. Following Marx's canonical lesson in part IV of *Capital*, Ramtin stressed that the purpose of capitalist technology is not to raise the quantity of output but the extraction of relative surplus-value: 'The ultimate test of any technology of production under capitalism is its actual power to increase surplus labour-time relative to necessary labour-time. However, this social aspect of the "measure" of the development of technology is translated into technical features.'[44] If 'measure becomes a technical feature', it means that the measure of value forges the machine as its instrument.

In this top-down perspective, capital is not the mother of invention: technological innovation usually happens via Research and Development units where capital directly subsumes scientific work. As Ernest Mandel highlighted in his study of late capitalism, it was during the twentieth-century boom that 'invention had become a systematically organized capitalist business'.[45] In the Schumpeterian variants of this perspective, popular also in Marxist circles,

43 Ramtin 1991, p. vii.
44 Ramtin 1991, p. 3.
45 Mandel 1975, p. 252.

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capital remains agnostic to the design of technology: technological development occurs according to its own logic and only thereafter capitals adopt the most fitting innovations through a process of 'selection'.[46] This is particularly the case in the account of new sources of energy in the industrial age. Andreas Malm has stressed that coal won over water as an energy source for mills, because the abstract quality of coal was 'selected' by the new regime of abstract labour: steam engines allowed factories to move close to urban areas and establish a clockwork discipline.[47]

Other value theories of automation see economic cycles independent from automation. In a tradition that runs from Robert Brenner's *The Boom and the Bubble* to Aaron Benanav's *Automation and the Future of Work*, it is the fall of profit and investments that cause underemployment, not automation per se.[48] In this reading, 'robots won't steal your job', because stagnation has already eroded the ground for production. Matthew Cole has criticised this view of stagnation, arguing that 'these approaches misdiagnose the problem, replacing technological determinism with economic determinism. Further, they misinterpret the recomposition of global capitalism and labour institutions while neglecting class struggle.'[49] According to Cole, de-industrialisation produced dynamism in the service sector and new forms of automation such as AI, whose economic rationale may contribute at the end to stagnation but whose dynamics have yet to be explained. Cole sides with Acemoglu and Restrepo who advance a more complex model of crisis and identify three effects of technological change.[50] The displacement effect is the substitution of machines for labour, fuelling both fears of unemployment and hopes of a work-free society. The productivity effect lowers production costs and prices, stimulating demand for goods and labour. The reinstatement effect offsets displacement by generating new tasks and demand for new skills.

Value theories of automation appear also in a radical variant that attempts to build an epistemology of technology based on the value form. This attempt is similar to what Alfred Sohn-Rethel did registering an epistemic effect of the money form on the rise of Greek philosophy.[51] Jonathan Beller and Seb

46 Smith 2004.

47 Malm 2013 and 2016; see also Mau 2023, p. 236: 'The steam-engine won out over water-powered mills in nineteenth-century British industry not because it was cheaper or more productive, but because water technologies were incompatible with competitive relations among firms and the antagonism between capitalists and workers.'

48 Brenner 2002; Benanav 2020; see also Smith 2020.

49 Cole 2025, p. 1.

50 Acemoglu and Restrepo 2019.

51 Sohn-Rethel 1978.

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Franklin argue that the abstraction of the value form, rather than the abstraction of labour, is what has influenced the form to information technologies, or digitality.[52]

1.5 *Towards an Organic Theory of Automation and AI*

In the capitalist mode of production, the machine has come to crystallise a social order, an organisation of labour, a technique of measurement, and an economic diagram. In short: a form of subjectivity, a labour form, a metric form, and a value form. Although each school of critical theory has often focused only on one of them in isolation from the others, the four dimensions are deeply imbricated and all shape the destiny of a technological form. In capitalism's logic, any increase in profit extraction implies a tighter division of labour. Any tighter division of labour implies a vertical division of labour that is a social hierarchy of skill. Any hierarchy implies a metrics. Any metrics implies previous conflicts and negotiations around cultural and economic values. In the capitalist mode of production, quantification of labour appears to be the road to automation, that, in its own, engenders and expands novel metrics of labour. One should consider whether, at the end, the very nature of capitalist technology is measure and hierarchy. Yet in a different mode of production, the machine could be the crystallisation of a different set of social relations, economic needs, and political values. It could be the crystallisation of an economic system, for instance, in which the organisation and calculation of labour would be governed by principles of value redistribution.

2 AI from the Perspective of Automation Theory

The first part outlined past theories of automation, pointing to the need for an organic theory capable of seeing together the forms of subjectivity, labour, measure and value. These have operated in concert throughout the modern history of automation and keep transforming themselves in the present. The second part shows that these past theories of automation are still useful to illuminate the current forms of subjectivity, labour, measure, and value in AI. Accordingly, the following presents *microwork* as the labour subjectivity of AI; *social patterns*, as the type of the division of labour and management of AI; *psychometrics*, as the social metric of AI; and *eigencapital*, as its value form.

52 Beller 2021; Franklin 2021.

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Taken together, these four aspects sketch an organic theory of AI from a socio-technical and historical materialist perspective.

2.1 *The Subjective Form of AI: Microwork*

In the early digital age of the 1980s, the *hacker* stood as the emblem of resistance within and against computer networks, later becoming a metaphor at large for the cognitive worker of post-Fordism and anyone engaged with information technology.[53] The hacker represented a short-lived utopia of emancipation in the information age, one rapidly subsumed by the start-up mentality. The rise of AI can be read as the full disintegration of the hacker subjectivity. The labour composition of AI is part of a long process of deskilling and declassing of digital workers that traces back at least to the 2000 dot-com crash, which resulted in the proletarianisation of the hacker and the making of a new *cyber-proletariat*.[54] This reserve army of digital workers and users has interacted with key dynamics of global society and has animated the alter-globalisation movements and the Arab Spring. One can suggest (as Antonio Negri among others did) that as much as the third technological 'revolution' of information technologies developed to counter the resistance of social movements after WWII and new forms of socialised work, in a similar way the fourth technological 'revolution' of AI is directed to neutralise the aspirations of global movements and the new social composition of cognitive work.

With the rise of the corporate Internet in the 2000s, a different figure of the digital economy emerged. The first kind of worker that is really native to the digital networks happened to be called a 'turker.' This term, an orientalist stereotype, designates a freelance worker hired to perform repetitive online tasks on the Amazon Mechanical Turk platform. Amazon CEO Jeff Bezos cynically defined turkers as 'artificial artificial intelligence', as they are employed to automate the very tasks that automation fails to accomplish.[55] Since then, the gig economy mediated by digital platforms expanded globally. The turker eventually became the prototype of the gig worker of the platform economy at large, from food-delivery riders to Uber drivers; similar platforms are still used today to outsource AI's ghost work across the world.[56] Today one could define all types of online work as *micro work*.

Notably, Amazon Mechanical Turk played a decisive role in the making of ImageNet, the first dataset of deep learning, so microwork is found at the very

53 Wark 2004.
54 Dyer-Witheford 2015.
55 The Economist 2006.
56 Moore and Woodcock 2021; Woodcock 2021; Gray and Suri 2019.

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first steps of the current AI revolution.[57] A decade later in November 2022, the release of ChatGPT marked the symbolic end of the paradigm of the knowledge society: an optimistic worldview that expected prosperity to flow from the virtuous proliferation of knowledge, while underestimating knowledge's proneness to automation. The hacker, who once aspired to become a cyborg or an intellectual worker, has ended up a micro worker micro tasking on the AI platforms of the vectorialist class (according to Wark the vectoralist class is the class that owns the means of production in information capitalism).[58] In the last paradox of the history of automation, gig workers today are compelled to purchase tokens of micro tasks in order to work at all: they are made to pay for the automation of their own work.

Microworkers and gig workers exemplify the precarious labour subjectivities and class composition of current AI. Their jobs are often 'bullshit jobs', as David Graeber called them, revealing the fraud of the promises of the knowledge economy and network society.[59] These subjectivities remain antagonistic: today, the distinction between hacker, gig worker, and microworker is increasingly blurred as they all engage in acts of 'algorithmic resistance'.[60] The resistance to dominant technologies has crossed the whole twentieth century up to the hackers movement and so-called Neo-Luddism in the digital age and includes more recent forms of resistance against AI and datacentres.[61]

2.2 *The Labour Form of AI: Social Patterns*

What is the structure of AI systems, and what materially shapes them? A simple analysis of their infrastructure confirms the labour theory of automation expounded above. The global infrastructure of AI is composed as follows: 1) a multitude of microusers and microworkers is constantly connected to 2) a planetary digital network in order to access 3) a centralised datacentre which is running 4) a large model previously trained on 5) a vast dataset. The input of this pipeline is data produced by human labour, social relations, communication, and culture – data that represents the collective production of knowledge.[62] One could say that the input and the output of AI are the same: microtasks. Microtasks are what AI models extract, and microtasks are what they automate. The concept of micro task resonates with similar analyses about the new

57 Deng et al. 2009; Denton et al. 2021.
58 Wark 2019.
59 Graeber 2018.
60 Bonini and Treré 2024.
61 Mueller 2021; Bonini and Treré 2024; Sadowski 2025; McQuillan 2022; Bender and Hanna 2025.
62 Muldoon et al. 2024.

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forms of power since the early 1990s: see, for instance, Gilles Deleuze's notion of the *dividual*. However, the general form of management of microtasks is what can be called *macro patterns*, or *social patterns*, to stress that it is the collectivity of cooperation that creates value for the AI economy. AI captures the 'condividual' recomposition of individual and dividual microtasks.

Social patterns have a history. The division of labour has become more complex through time, innervating into the social fabric outside the factory and organising into extended patterns of life.[63] The consequence of this expansion is that also the techniques and instruments to trace and measure it have evolved. The time and motion studies of Taylorism turned into urban rhythm analysis and trajectory analysis (or *trajektology*) that is used today to map movements of workers, drivers, and users in the gig economy.[64] These dynamic social patterns and urban trajectories draw the outline of labour cooperation: the general worker (*Gesamtarbeiter*) in the current mode of production.[65] The power of current AI models is their capacity to trace and adapt to a global and flexible collective worker. Through AI, the division of labour has become the object of complex techniques of patterns-of-life analysis at the collective scale (which are the same techniques used by the military and intelligence) and of micro intentions analysis at a sub-individual scale.[66]

Here, AI represents an 'analytical intelligence' of labour.[67] It generates artefacts by imitating the social division of labour that is key to the performance of any task, from composing an email to describing an image. AI models can now encode relations of any kind: they are termed 'multimodal' precisely because they record correlations between artefacts as diverse as images and texts (consider the generation of an image from a simple prompt). This multimodal capacity blurs the distinction between artefacts, between image and text for instance. With AI, all forms of knowledge fall under the same statistical structuralism of social relations. From a philosophical standpoint, nothing prevents us from stating that the content of knowledge is an abstract relation, an organisation and disposition of the world. All knowledge is a division of labour at large – a configuration of relations. Whether one looks at its genealogy, its inner architecture, or its artefacts, the constitution of AI is the global division of labour. The division of labour constitutes the genealogy of AI and,

63 Pasquinelli 2023, p. 237.
64 Lefebvre 2004; Brighenti and Pavoni 2023.
65 As I do in the book, I use the figure of the *Gesamtarbeiter* to read beyond the idea of the general intellect (Virno 1990, Vercellone 2005, Pasquinelli 2023, p. 95).
66 Chamayou 2015; Chaudhary and Penn 2024.
67 Daston 2018.

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conversely, AI projects back onto society a new division of labour, which it orchestrates like a vast planetary automaton. Ultimately, in its capacity to model almost any form of human activity and social relation, machine learning can be seen as the project to automate the very process of machine design and model making – which is to say, the automation of the labour theory of automation itself.[68]

2.3 *The Metric Form of AI: Psychometrics*

The idea of 'knowledge society' often operated as a discriminatory paradigm, elevating a new 'labour aristocracy' in the same way that guilds celebrated skilled artisans during the industrial age. As Quinn Slobodian observes, terms such as 'information age' and 'knowledge economy' began to circulate in the 1990s, at the same time when neoliberal elites were rediscovering the IQ test (a technique of psychometrics) as a means of class, gender and racial discrimination.[69] This moment was marked by the publication of *The Bell Curve: Intelligence and Class Structure in American Life*.[70] This racist book argued that the IQ test demonstrates that class division is not historical but natural and motivated by ethnic background. The IQ test became an alibi for neoliberal circles to justify low salaries for Black Americans and support the idea of 'intelligence hierarchies' or 'neurocastes'.[71]

The measure of skill is key for the labour market to divide and categorise workers. Since the early twentieth century, psychometrics (in the form of IQ tests among others) has played the role of such social measure. Psychometrics belongs to the controversial legacy of Alfred Binet, Charles Spearman and Louis Thurstone; it rose to dominance in US psychology departments in the 1950s, consolidating as a branch of applied statistics. Statistics itself has never been a neutral discipline. From its origins in state administration and eugenic policies, it has functioned as a technique of normalisation: a means of defining the social 'average', calculating deviations and abnormalities, and regulating populations.[72] As Stephen Jay Gould showed in *The Mismeasure of Man*, psychometrics emerged from the pseudo-science of craniometry and was deeply implicated in supplying the pseudo-scientific rationales for hierarchies of class, race and gender.[73]

68 Pasquinelli 2023, p. 248.
69 Slobodian 2025, p. 94.
70 Herrnstein and Murray 1994.
71 Slobodian 2025, p. 93.
72 Foucault 1978; Hacking 1990; Porter 1995; Desrosières 1998; Pasquinelli 2017.
73 Gould 1981.

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It is revealing that the mathematical form of psychometrics (that is, multidimensional analysis) is found also at the origin of the current form of AI, deep learning, which is an evolution of artificial neural networks. In the 1950s, Frank Rosenblatt developed the first artificial neural network Perceptron. He did this not simply by imitating the structure of biological neural networks (as widely repeated), but by implementing techniques of linear algebra and multi-dimensional analysis that he, as a trained psychologist, adopted from psychometrics.[74] The Perceptron was invented by implementing statistical techniques to automate the recognition of visual rather than psychological patterns.

The IQ test and AI are part of the same sociotechnical development in which the former operates as a social metrics and the latter as its technique of automation. If the statistical measurement of intelligence was instrumental to reinforce class, race and gender discrimination, one cannot but notice a structural similarity with the debate on social bias in AI today. It seems that the issue of class, race and gender bias that affects AI datasets and models is a second (mechanised) reiteration of the old system of class, race and gender discrimination that was implemented via psychometrics. AI bias is not a mere technical issue but is deeply imbricated with the history of social metrics and techniques of discrimination.[75] Although IQ tests started to be used in the US army and schools already in the early twentieth century,[76] its revival today, in the neo-authoritarian culture associated with the alt-right and Silicon Valley, signals that the economic order of AI demands a social metrics to discipline the population and workforce.

2.4 *The Value Form of AI: Eigencapital*

AI's power relies on the scale of its collective formation, on the accumulation of labour and knowledge that is extracted from the global society and automated through vast statistical models that operate as a truly *Gesamtarbeiter*, or general worker. AI is tendentially a monopolistic technology, because its horizon of capture is the totality of cooperative labour, social communication, collective knowledge and cultural heritage at a global scale. In similar terms, in the *Grundrisse*, Marx defined machinery as 'the accumulation of knowledge and of skill, of the general productive forces of the social brain' and 'the most adequate form of capital as such'.[77] But in which way is AI measuring

74 Pasquinelli 2023, p. 205.
75 Benjamin 2019; Chun 2021.
76 Gould 1981.
77 Marx 1973, p. 694.

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and computing the overall field of collective knowledge and extracting surplus value? In AI systems, it has been established that the measuring unit of collective knowledge is the *token* and the computing unit of tokens embedded in a multidimensional space is the *vector*. This essay is not concerned only with the definition of *token* and *vector* in computer science, but rather with their translation into political economy. In a sort of Babbage principle expanded to a planetary scale, the monopoly of AI is constituted by the accumulation of units of micro tasks known as *tokens*, which become the basis for a novel calculus of relative surplus labour known as *vector calculus* (in computer science, a token is a measuring unit of language and instructions that does not correspond to units of natural language but to how algorithms fragment it in the most economical way).[78] The token is also the cost unit of the micro tasks that are automated by AI datacentres. Users send short prompts to AI models that are monetised in tokens and receive large outputs (micro tasks), which are monetised in tokens as well. The number of users, their time spent on AI platforms, the number of automated micro tasks, the cost per token, and the ratio of parameters per token define, among other factors, AI's economic dimension.

The value form of AI is *vector capital* (or *eigencapital*), understood not just as the formula for the mechanisation of collective knowledge, but also for the calculation of the productivity of labour, language and culture at large. The rise of algorithmic governance prompted Marion Fourcade and Kieran Healy to define *eigencapital* as the calculus of individual and collective data to establish their ranking, value and productivity in the 'ordinal society'.[79] Training datasets project collective knowledge as data points in multidimensional space, while AI models attempt to build a stable representation of them through linear algebra. This technique is not new either in economics, where it is used to calculate *eigenvectors* and *eigenvalues* of economic data (that is the patterns of economic flows across different sectors and the tendency of each pattern to grow or not), or in the sociology of knowledge, as Pierre Bourdieu already advanced 'geometric modelling to quantify the basic dimensions of social space and explore sociological hypotheses'.[80] The making of AI models

78 Caffoni 2026.

79 Fourcade and Healy 2016, and 2024, p. 117: 'It might take the form of some vector of information that summarizes your situation and value across many features – something that compactly represents your position in the multidimensional space of classification situations. It would, in short, characterize your social location. In data analysis, this procedure often involves the decomposition of matrices of data into orthogonal eigenvectors, the better to characterize them … From an individual's point of view, these quantities and their representations would be a kind of resource. Call it eigencapital.'

80 Lebaron 2009, p. 13.

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is a form of automation in which one could say that *vectors replace workers*, as vectors ultimately calculate the many variables of labour cooperation and its spontaneous intelligence.

Marx first proposed the idea that the division of labour performs a sort of a mathematical equalisation of the collective worker and this insight can be easily extended to the genesis of the structure of machinery.[81] As Kenji Mori suggested, the machinery system can be understood as 'a mathematical fixed vector of physical and labour inputs.'[82] Similarly, from a mathematical point of view, the vector capital or *eigencapital* of an AI model could be defined as the equalisation of all the data points projected on its vector space; more specifically, as the ratio between AI model parameters and the dimension of the dataset. This ratio, that is the equalisation of social variables into a model, points to something about the constitution of fixed capital that in previous stages of automation remained unclear. This ratio, as Marx hinted, is an index of the transformation of living labour into dead labour – today, of living knowledge into machine knowledge. The idea of a vector capital or *eigencapital* in AI is a quantitative one: it is about the calculation of relative surplus value, in this sense quite different from qualitative notions such as cultural and cognitive capital.

Vector capital is the value form of AI monopoly, yet a very dynamic and volatile one. Given the turbulent ecosystems of data extractivism, AI business is based on a *differential monopolistic rent* that runs along and competes upon the dynamic valorisation of knowledge. The concentration of collective knowledge and cultural heritage in AI models represents a new dynamic form of knowledge rent that surpasses the previous (and temporary) dominion based on intellectual property rights[83] and extends the first forms of knowledge extractivism inaugurated by algorithms such as Google's PageRank that started already in the 1990s to build vast datacentres.[84] AI models attract investments because of the acceleration of this concentration, because of the gradient of their differential rent on collective knowledge. AI models and datacentres represent a new economic configuration and evident scale shift: whereas industrial machines were a crystallisation of a specific division of labour and forms of knowledge, AI models are a dynamic modelling of collective knowledge and labour at a global scale.

81 Marx 1981, p. 465. See opening quote.
82 Mori 2019, p. 317.
83 Durand and Milberg 2020; Rikap 2021.
84 Pasquinelli 2009.

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The globalisation of information technologies and the formation of new technological monopolies in the twentieth century has brought attention to another value form rather than profit: monopoly rent. Mandel already noticed that: 'in accordance with the logic of late capitalism … technological rents have become the main source of surplus-profits.'[85] Rent is key to understanding the economy of information technologies including AI, as their market and workforce are immediately global. Technological rent is linked however to crisis, Mandel reminded us: 'the absolute inner limit of the capitalist mode of production [lies] in the fact that the mass of surplus-value itself necessarily diminishes as a result of the elimination of living labour from the production process in the course of the final stage of mechanization-automation'.[86]

3 AI in the Long Wave of Economic Cycles

The previous overview of automation theories, centred on the microeconomics of automation, should be used to clarify the dynamics of technological cycles in the long run, that is, the macroeconomics of automation. AI belongs to the 'long century' of knowledge automation that began with the industrial age. Shifting from microeconomics to macroeconomics, from a synchronic to a diachronic perspective, the third part engages the role of technology and AI in the long-wave theory of capitalist development and Ernest Mandel's critique of it. Taking Marx's formula of the rate of profit as a prism through which to read labour and technology together, this third part extends Mandel's insight to the study of the rise (and potential collapse) of the social order of AI.

3.1 *Reading AI in the Long Wave Theory*

Any theory of automation (and especially an ambitious 'organic theory of automation') should be set in motion and studied within historical dynamics. Marx provides a model to study the development of technology in the formula of the rate of profit based on the notion of organic composition of capital. Despite its imprecise formulation and the confused literature that followed, as pointed out by David Harvey and Alfredo Saad-Filho, the formula of the rate of profit illustrates the mediation of technology in the antagonism between labour and capital.[87] This formula reads the rate of profit as the proportion between surplus-value and the sum of constant capital (machinery and raw

85 Mandel 1975, p. 252.
86 Mandel 1975, p. 207.
87 Harvey 1982, pp. 126, 207; Saad-Filho 1993.

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materials) and variable capital, that is human labour. In Marx, surplus-value reads also as labour exploitation and, therefore, the rate of profit reads also the rate of labour exploitation.

$$p = \frac{s}{(c + v)}$$

s: surplus-value
c: constant capital [⊃ machinery]
v: variable capital [⊃ labour]

Within capitalist dynamics, this formula of the rate of profit is usually interpreted as follows: the more automation (or AI, in this case) is introduced in production, the less workers are employed, the less surplus-value then is extracted, therefore the rate of profit falls. Yet this movement can take a different turn. When automation is introduced, indeed workers are replaced, but new skilled and unskilled workers are required and employed, more surplus-value is extracted, therefore the rate of profit grows. Automation first replaces then displaces and may multiply workers. However, when automation saturates the sphere of production and circulation with its applications and artefacts, the market stagnates, surplus-value falls again and so does the rate of profit. This is a common interpretation, one that overlooks social autonomy and workers' agency. The formula can also help us see how workers' resistance raises the cost of labour and forces capital to develop new technologies of automation such as AI, which replaces workers in the short run but displaces them to new jobs in the long run. At the end, the formula seems to describe not a fall but more like a cyclical development. The fall of the rate of profit has to be read in different ways in different economic systems. In a competitive economy, it is an indicator of crisis, but in non-competitive economies it may not. Even Adam Smith interpreted it as a redistribution of wealth.[88]

In his books *Late Capitalism* and *Long Waves of Capitalist Development* Ernest Mandel revisited the long wave theory of capitalist cycles that was introduced by the Soviet non-Marxist economist Nikolai Kondratieff to interpret Marx's formula of the organic composition of capital.[89] Trotsky had criticised Kondratieff for providing an endogenous theory of economic cycles and advanced his own exogeneous interpretation in which economic cycles are not driven by internal dynamics only, such as the fluctuations of the financial markets, but mostly by external factors such as class struggle and international

88 Arrighi 2007, p. 46.
89 Mandel 1975 and 1995; Kondratieff 1922, 1935.

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wars.[90] It was Joseph Schumpeter who canonised the long wave theory and named its cycles as 'K-waves' as a credit to Kondratieff.[91] Schumpeter in particular was responsible for consolidating the idea that economic cycles are essentially tied to technological innovation. Mandel explored a position in between Schumpeter and Trotsky, maintaining however an externalist reading of economic cycles, in which exogenous factors (social struggles) are more influential than endogenous factors (financial dynamics) in driving technological innovation and economic growth.[92]

Mandel insisted that technological cycles are not autonomous, but they are bound to economic and political cycles.[93] Here too he mainly followed Marx's theory of automation, according to which innovation is not driven by science, but by the reorganisation of the social relations of production, which require and shape new means of production. No technology can be separated from the organic division of labour it implies. Each technological era, Mandel argued, is organised around its own distinct system of machines, and each such system presupposes, in turn, a corresponding form of the labour process.[94] He traced a succession in which machines operated by craftworkers were followed by machines operated by machinists, and these by assembly lines involving deskilled workers – a phylum of machinic assemblages that one can extend up to the age of information and AI. This succession, however, is not one of smooth technical progress. Mandel observed that the passage from one configuration to the next has always provoked working-class resistance and, conversely, that capital cannot raise the rate of profit far enough to transform the whole economy until it has first broken the organisational strength and militancy of workers.[95]

> [E]ach of these revolutions in labor organization, made possible through successive technological revolutions, grew out of conscious attempts by employers to break down the resistance of the working class to further increases in the rate of exploitation. The first technological revolution was clearly an answer to the struggle of the British workers to shorten the normal workday. Marx himself commented on this at length in *Capital*.

90 Trotsky 1941.
91 Schumpeter 1939.
92 Mandel 1975 and 1995.
93 Mandel 1995, p. 29.
94 Mandel 1995, p. 33. 'Each specific technology, radically different from the previous one, is centered around a specific type of machine system, and this, in turn, presupposes a specific form of organization of the labor process'.
95 Mandel 1995, pp. 33, 88.

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> The second technological revolution was closely related to the increasing resistance of the strong crafts unions, both in the United States and in Western Europe, to more direct control by management over the work process; in fact, Taylorism arose directly out of the attempts to impose such direct control. Likewise, the third technological revolution had a direct link to the growth of unionization among semiskilled mass-production workers and to the need to whittle away the power of control over conveyor-belt production made possible by union strength of that type.[96]

The design of new technologies, and their shaping of the division of labour, respond to the need of capital to break down the resistance of the working class and place not only labour but social relations at large under a new discipline. This is why information technologies and AI, so often described as the main drivers of the current economic cycle, should instead be read as the expression of a new social order and a new division of labour across society. Any theory of automation that aims to be systemic must begin from this inversion: technological order follows social order.

Mandel's theory of the long waves of capitalist development is a synthesis of intra-economic and extra-economic dynamics, and its distinctive feature is an asymmetry between the two phases of the cycle. The passage from an expansionary wave into a depressive one is endogenous, following from the internal logic of accumulation itself. The passage from crisis to growth is exogeneous, driven by external forces that transform the historical and social context, especially working-class resistance.[97] The shocks Mandel had in mind were of this order: wars and revolutions, the defeat or victory of organised labour, the opening of new territories and new sources of cheap raw materials. Growth cannot be generated by the economic mechanism alone, it has to be induced from the outside.

Against both technodeterminism and economicism, Mandel recognised that the cycle of social struggles is 'relatively autonomous' from the technological and economic cycles. If the upturn depends on extra economic conditions, then the cycle of social struggle cannot be a mere reflex of the economic one,

96 Mandel 1995, p. 35.

97 Mandel 1995, p. 42. 'The downturn (the passage from an expansionist long wave into a depressive one) is endogenous, whereas the upturn is not, but rather is dependent on those radical changes in the general historical and geographic environment of the capitalist mode of production that can induce a strong and sustained upturn in the average rate of profit'.

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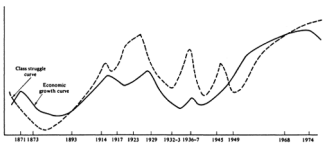

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FIGURE 1 Long waves in European class struggle and economic growth
FIGURE FROM MANDEL 1995, P. 39

and Mandel accordingly described it as 'relatively autonomous'.[98] He illustrated the claim with a graph plotting the frequency of strikes per year against the long waves of accumulation, the two curves running visibly out of phase. His own formulation was cautious: there exists a long cycle of class struggle that is relatively independent of the alternation between faster and slower accumulation, even while remaining interwoven with it to some degree.[99]

Mandel recognised that a variety of external 'system shocks' are crucial for ending an economic depression and starting a new wave of expansion, including: shifts in consumption, changes in labour organisation, outcomes of social struggles and strikes, fluctuations in the labour supply due to migration, monetary hegemony, wars and revolutions, the expansion and contraction of credit, and shifts in core-periphery relations.[100] In synthesis, long wave cycles see a dialectical relation between cycles of social struggles, cycles of technological innovation, and cycles of capitalistic growth and crisis. The quantitative study of working class conflicts and political organisation will be continued by Giovanni Arrighi and Beverly Silver.[101] Silver in particular initiated the World Labour Group Database to bring statistics of social conflicts into economic analysis. However, Hardt and Negri criticised Arrighi for seeing cycles of social struggles as reactive rather than active in the unfolding of global economic cycles.[102]

These reflections remain valid today as the long wave theory influenced a key framework of twentieth-century governance such as *The Limits to Growth* report and indirectly also the Anthropocene debate.[103] The report relied on a computerised world model developed by Jay Forrester that, reflecting a cybernetic worldview, stripped social agency from economic analysis and

98 Mandel 1995, pp. 37, 42.
99 Mandel 1995, p. 39.
100 Mandel 1995, pp. 116–17.
101 Arrighi et al. 1995, Arrighi and Silver, 2002; Silver 2003. See also Screpanti 1984; 1987.
102 Hardt and Negri 2000, p. 238; Arrighi 1994.
103 Meadows et al. 1972.

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contributed to turning the cyclic model into an asymptotic curve. In this way it grounded the Great Acceleration studies and promoted a vision of world dynamics driven primarily by technological forces ~~only~~.[104] To remedy such a shortcoming, Jürgen Renn has recently suggested adding the *ergosphere*, or the sphere of labour and knowledge production, to the Anthropocene world model composed by geosphere, biosphere, technosphere, and infosphere (which includes today the global infrastructure of AI).[105] ~~In conclusion,~~ the reference to the Anthropocene studies is to emphasise that a convincing macroeconomic model of the world system is still missing. AI, as any other technological cycle, will face upturns and downturns. The ergosphere of microwork will continue fighting with the technosphere and infosphere.

3.2 *Model Collapse and Social Autonomy*

Is the cycle of AI about to repeat the pattern of past technological cycles? According to the previous overview, AI follows the same genesis of other technologies and confirms the theories of automation as known since the political economy of the nineteenth century. In its adaptive architecture, however, AI marks a new phase in that history: AI appears to be the automation of the labour theory of automation itself, that is the automation of the automation principle. Models no longer encode a fixed procedure such as in the old assembly lines, but adapt dynamically to different sources of data and this multimodal capacity allows them to automate labour across different domains at once. This feature makes AI the general purpose technology *par excellence*, but also discloses a new intrinsic limit that becomes manifest in the issue of model collapse. In general, it should be recognised that any theory of automation implies a theory of de-automation, or obsolescence, which this essay could not explore for reason of space.

Like any piece of machinery, AI models experience obsolescence. The turnover seems quite rapid. Models from a few years ago are replaced by new ones and quickly lose value. But AI models also feature a technical kind of deterioration known as model collapse, in which obsolescence itself has a sociotechnical dimension. Model collapse is the declining performance of generative AI models when they are trained not on genuine data but on content that has been generated by AI itself (texts and images, for instance, that after being published on the web are incorporated into training datasets).[106] Model collapse is also termed 'model autophagy', as the model happens to 'eat' its own

104 Forrester 1971; Steffen et al. 2004; Engelke and McNeill 2014.
105 Renn 2020.
106 Shumailov et al. 2024.

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AQ 6

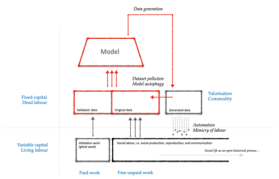

FIGURE 2 Model collapse from the perspective of political economy

data in a recursive loop that degrades its statistical resolution (sometimes called 'slop'). In this sense, model collapse that can be seen also as a diagram of valorisation (and conceptually display quite a few similarities with the formula of the falling rate of profit).

Let's consider the example of Large Language Models (LLMs). They encode human knowledge from canonical corpora of books as well as spontaneous textual sources such as websites, forums and chats. They excel in translation and in reproducing knowledge of these past archives, yet their output is often regurgitated online and pollutes the sources that will be used for training AI and causing a loss of linguistic and semantic diversity. Similar instances of entropic decline affected any media revolution since printmaking, yet the novelty in the case of AI is that *the dissemination of machine artefacts recursively affect the accuracy of the machine itself that originated them*. AI is precipitating an economy of scarcity, valorising all cultural heritage and high quality knowledge that has not been corrupted by generative AI. The release of ChatGPT in November 2022 can be taken as a watershed date between the 'original' pre-AI cultural heritage and post-AI cultural heritage that is potentially corrupted by AI artefacts and their statistical normalisation. More alarming, it has become known recently that AI companies buy second-hand book collections of high-quality literature in order to train their model, yet destroy them immediately afterword, in this way trying to secure a privileged access to high quality knowledge.[107]

Model collapse is not a technical issue only, but it should be interpreted also as an exogenous limit in a larger perspective. Model collapse points to the socioeconomic limit of any apparatus of automation ('the human in the loop') and eventually it provides a tangible analogy for the crisis of automation. A sort of 'model collapse' always existed in automation as degradation of its design in the continuous tension to capture the multiplicity of living labour. As seen earlier in Mandel's criticism of the long wave theory, the antagonism of labour is

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what often triggers new waves of automation and keeps them alive. As soon as a new division of labour emerges throughout society, technology must adapt and evolve to capture it. However, this process is never linear and complete, but spurious and conflictive. Similarly, AI models strive to adapt to new forms of social life and need continuously fresh data to provide an updated picture of the collective intelligence. In short, any form of automation (including AI) is never autonomous and maintains a critical dependency on the evolution of society and the need of living labour.

Whatever the outcome of model collapse and the AI bubble will be, the social dialectics of AI is already manifesting itself. The development of AI as a planetary technosphere is forcing the recognition of political contradictions that should have been registered long ago. First, the application of AI has made clear that any form of labour, practice, and social activity is a source of knowledge and intelligence, that manual labour is mental labour, thereby calling into question the division between manual and mental labour and the social hierarchies separating manual and mental workers. Second, the infrastructure of AI has revealed the ecological and energetic footprints that are implicit to the knowledge economy and the material infrastructures it requires to operate. Third, the scale of AI has demonstrated again that the economic sphere is a product of collectivity and that, in particular, social cooperation is the source of valorisation. As known, capitalism does not exploit individual work but the surplus of production that emerges only through cooperation: in the same way AI mirrors and captures the surplus labour of collective intelligence. It is for this reason that the progress of AI compels us to take seriously the proposal of AI collectivisation and of the means of production more broadly.

In conclusion, the most important problem that AI has engendered is probably the idea that AI embodies the ultimate automation of political agency, an idea that should be also brought to terms with the longer history of class struggles. At the end of this complex excursus, then, it is worth remembering Mandel's late reflections regarding the role of political organisation within the long term dynamics of capitalism delivered at the conference 'The Long Wave Debate' in 1989.[108] His words still resonate timely in the age of AI monopolies and technonationalism:

> To bring the controversy to its vital implication: is the class struggle cycle mechanically determined by economic forces resulting essentially from levels of employment (i.e., from fluctuations in the reserve army of

108 Verspagen 1989.

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> labor)? Do long-term depressions make crushing defeats of the working class unavoidable? Was Adolf Hitler's victory in 1933 inevitable? Or should one rather say that there is indeed a relative autonomy of long-term class struggle results, a relative desynchronization of the class struggle and the ups and downs of investment, output, employment and income? Can the subjective factor in history … make a decisive difference between victory and defeat of, for example, fascism?[109]

Acknowledgements

I thank Pietro Omodeo, Alfredo Saad-Filho, Tommaso Guariento, Paolo Caffoni, Francesca Carta, Giovanni Fava, Giorgio Ciani and Giorgio Cesarale for comments and feedback on a previous version of this text.

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109 Mandel 1995, p. 114.

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