Theories of Automation from the Industrial Factory to AI Platforms: An Overview of Political Economy and History of Science and Technology

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1. Introduction

What theories of automation have respectively developed in the fields of political economy

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and history of science and technology (HST) and what is their relationship? This essay undertakes a comparative review of these two fields with the following caveat: the focus is not to rehash the relationship between technology and society *ex-post* and propagate descriptive accounts (such as those studying the "impact" of new media on society), but to investigate causal models and explanatory accounts of technological history *ex-ante*. How does technology progress? Why is it designed in one way rather than another?

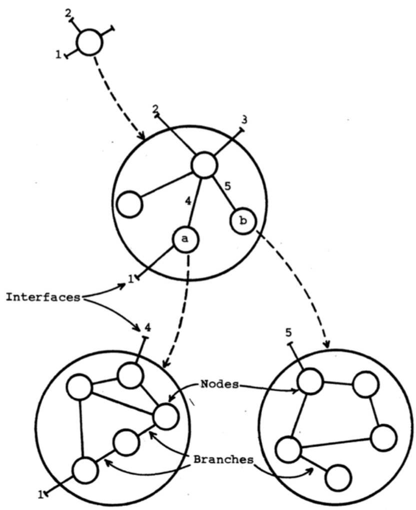

Figure 1.
from Conway, Melvin E. (1968) *How Do Committees Invent?*, in "Datamation", 14(4), p. 29.

In political economy, a general consensus is found around the following thesis: *technological development is driven by an economy of time (making things faster) as well as of space (organizing things better), which encompass an economy of resources (making things cheaper) and particularly of labour (paying people less).* This labour component, which is part of a broader social antagonism, is quite crucial. The way in which labour is measured and remunerated, and whether or not workers resist such measure and remuneration, crucially affects technological evolution. In synthesis, within political economy, the matrix of forces driving automation can be viewed from at least three perspectives: capital investments (seeking profit), the design of the division of labour (saving costs), and the standpoint of workers (resisting exploitation). Accordingly, automation theories in political economy can be divided, for reasons of presentation, into three groups: value theories of automation, labour theories of automation, and standpoint theories of automation. As it will be shown below, all these positions are obviously entangled and dialectical. In looking for a convincing explanatory and causal framework of technology development, this essay revisits in particular the labour theory of automation as the missing link between value and standpoint theories and endeavours to shed light on its origins, harking back to the 19th-century political economy.

Value theories of automation conceptualize it predominantly as a dynamic process that is shaped by the imperatives of capital and investment cycles from the outside. This perspective can be traced from Ernest Mandel's seminal work *Late Capitalism* (1972) to Robert Brenner's *The Boom and the Bubble* (2002), whose influence reverberates also in Aaron Benanav's *Automation and the Future of Work* (2020). Within this approach one can include also Ramin Ramtin's *Capital and Automation* (1991) and Neo-Schumpeterian positions popular in Marxist circles (Smith 2004). These theories explain the design of automation as a process that is "selected" *from the outside* by the needs of capital: technological development occurs according to its own logic (e.g., through the application of science to production) and only thereafter capital "selects" (Smith 2004) the most fitting innovations that would accelerate production and secure investment returns.

Labour theories of automation explains automation from the perspective of the material logic of production and the division of labour, or labour process (i.e., from the point of view of labour rather than simply the market). In this lineage, Harry Braverman's *Labour and Monopoly Capital* (1974) is probably the most influential work as it initiated the *labour process theory* and deskilling debate in the Anglo-American world (Smith 2015). Aside considerations about the mechanisation of manual labour, Braverman contributed to rediscover also the project for the *mechanisation of mental labour* in Babbage's "calculating engines" and to stress the influence of political economy on Babbage's early experiments of automated computation. Friedrich Pollock's *Automation* (1956) was another early seminal account stressing the role of information technologies in the industrial assembly line, influencing also the Frankfurt School's views on technology in general (Lenhard 2024).

Standpoint theories of automation see automation as driven by social antagonism and hierarchies of class, gender, and race, i.e., from processes of subjectification that are at the same time processes of resistance. Marx (1867, 552-553) 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". The history of machine breakers and technological sabotage run from the 19th century Luddites (Hobsbawm 1952) and Machinery Question (Berg 1980) to the 20th century feminist and hacker movements (Mueller 2021) and recent practices of "algorithmic resistance" in the gig economy (Bonin and Treré 2024). Italian *operaismo*, in particular, has viewed labour struggles as a primary and not secondary actor in capitalism's technological advancements (Panzieri 1961; Tronti 1966). For instance, Alquati (1962; 1963) highlighted the central role of workers at the Olivetti computer factory as producers of "valorising information" in the cybernetic process (Pasquinelli 2015). Similar approaches were observed also in the US, with David Noble's critique of Braverman's deterministic focus on the labour process (1984).

The expression "standpoint theory" comes originally from feminist studies where it emphasises subjectivity as an antagonistic and active force also in knowledge production (Gurung 2020). In this respect, feminist authors, from Ruth Schwartz Cowan (1983) to Astra Taylor (2018), have revealed the ambivalent impact of automation on reproductive labour (a sphere often overlooked in political economy which is primarily focused on productive labour) arguing that it made women work more, not less. At the same time, Shulamith Firestone (1970) and Donna Haraway (1985) stressed the potential for women's emancipation through technology. From a deeper historical perspective, Hilary Rose and Steven Rose (1976), Sandra Harding (1986), Evelyn Fox Keller (1985), and Silvia Federici (2004) have expounded the rise of modern rationality and mechanical mentality in relation to the transformation of women's bodies and the collective body into a docile and productive machine. In other words, they noticed that social relations became an abstract machine before the regime of the industrial factory turn them in actual machines. Ultimately, Neda Atanasoski and Kalindi Vora (2019) have described how the dreams of full automation (which include AI) have been always grounded on the "surrogate humanity" of enslaved, servants, proletarians, and women, that make possible, through their invisibilised labour, the universalistic ideal of the autonomous (white and western) subject. "Automation is a myth" concludes Munn (2020), because it is often used to make all people work more, not less.

2. Automation theory in the 19th century political economy

The idea that organization of labour has to become "mechanical" on its own, before machinery comes to replaces it, is an old fundamental principle of political economy (Aspromourgos 2012; Pasquinelli 2023, 239). Adam Smith was the first to have sketched a *labour theory of automation* in *The Wealth of Nations* (1776) by recognising that new machines are "invented" mostly by imitating the organization of tasks in the workplace: "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". Also, Hegel's notion of *abstract labour*, as labour that gives form to machinery, was indebted to Adam Smith, who Hegel commented already in his Jena lectures (1805-06). Nevertheless, it fell to Babbage to systematise Adam Smith's insight in a consistent labour theory of automation, that he exposed in this way:

> 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. (Babbage 1832, pp. 131-136)

What does it mean that "the division of labour suggests the contrivance of tools and machinery to execute its processes"? It means that *the design of the division of labour shapes the inner design of technology*; that labour gives form to automation first, rather than the other way around. Babbage complemented this theory with the *principle of labour calculation* (known as the "Babbage principle") to indicate that the division of labour also allows another key function: the precise computation of labour costs (Babbage 1832, 137).

Interestingly, Babbage maintained these two principles as a cornerstone of his projects of "calculating engines" such as the Difference Engine and Analytical Engine, which are considered prototypes of the modern computer. Babbage was also inspired by the French mathematician Gaspard de Prony who had first the idea of applying Adam Smith's principle of the division of labour to hand calculation and in particular to the calculus of logarithmic tables. Babbage took De Prony's algorithm, known also as "method of difference", and sought to embody its organization into a mechanical artefact. In synthesis, Babbage's design of computation moved from the idea to apply Adam Smith's principle of the division of labour to hand calculation and to mechanise, for the first time, such organization of tasks. The case of Babbage's calculating engines testify that all forms of automation (mechanical as well as informational) may be considered as evolving from the same principles. In the scholarship of the 20th century, this relation between the early project of automated computation and the political economy of labour got somehow forgotten and started to be revisited at least only since Braverman (1974) as mentioned above.

Mimetic theories of automation and variants of the labour theory of automation are actually found in many disciplines. The whole field of robotics and in particular the sub-field of bionics are based on the systematic imitation of the morphology of human and non-human living beings (Freyberg and Hauser 2023). In computer science and programming, the so-called Conway's principle states that the design of a complex artefact such as software mirrors the relations of communication between the parts of the company or organization that contributed to it: "organizations which design systems (in the broad sense used here) are constrained to produce designs which are copies of the communication structures of these organizations" (Conway 1968, 31). In engineering, the Internal Model Principle states that a "regulator must create a model of the dynamic structure of the environment" (Bengtson 1977, 333) meaning that the environment shapes the internal model first. This is, in fact, a typical principle cybernetics and within this lineage of techniques of modelling, one could also include the idea of "internal representation" in artificial neural networks (Clark and Toribio 1994) which remains central in today's AI architectures such as deep learning.

3. Automation theory in the history of science and technology

In the history of science and technology (HST), the problematics of automation has acquired a different dimension than in political economy. One could argue that in political economy the central principle of research is capital accumulation (or labour politics), while in HST the production of new instruments and knowledge. Indeed, one easily perceives that both fields tend to gravitate around their own epistemic centre and give different explanations of technoscientific developments, and yet can the two perspectives illuminate each other? What follows illustrates how HST has incorporated insights and findings from political economy and how the latter could benefit from reciprocating this knowledge transfer.

A theory of automation is implicit in any theory of scientific development as science cannot be separated from its own experimental artefacts and instruments of speculation. The debate on the status of scientific paradigms is vast: here it is framed and illuminated only from the point of concern, that is the role that tools, techniques and technologies of automation play in the history of such paradigms. For a matter of presentation, HST is divided in three main theories: internalist, culturalist, and externalist. Internalist theories often describe techno-scientific development unfolding according to internal principles (see the idea of scientific revolution in Koyré 1939 and paradigm shift in Kuhn 1962); culturalist theories open up technoscience to the influence of the social environment and engage with a constructivist approach (Simondon 1958; Shapin and Schaffer 1985); externalist theories attempt to integrated it within a larger socio-economic dynamic. This is not the place to illustrate the three approaches, as the recent historical epistemology of science and technology has provided exemplary syntheses (Badino et al. 2022; Omodeo 2019; Ienna 2023).

An interesting parallel can be registered at this point between HST and political economy: *internalist theories* in the former appear epistemologically symmetrical to the *value theories of automation* in the latter. Both theories in fact focus on a principle independent from external factors: in internalist HST, science transforms itself regardless of external contingencies, whereas in political economy's value theories, capital finds its own way to accumulate value regardless of technical and scientific achievements. However, at a different level, the two fields seem to have cooperated. The turn to the centrality of labour in political economy has projected new perspectives also in HST and it is through the study of such centrality that HST has absorbed some key notions of political economy in its own.

HST has been marked by the influence of political economy at least since Boris Hessen (1931) foundation paper "The Social and Economic Roots of Newton's Mechanics" in which he recorded the influence of the industrial age technologies on Newton's *Principia*. Another key contribution came from the Polish economists Henryk Grossmann (1935), a figure close to Frankfurt School who analysed "The Social Foundations of the Mechanistic Philosophy and Manufacture". Freudenthal and McLaughlin (2009, 4) encapsulated Hessen and Grossmann's thesis in this way: "Economics is said to present demands, which pose technical problems, which generate scientific problems". The merit of the Hessen-Grossman thesis is that it draws a complex *epistemic scaffolding* of human civilisation in which socio-economic forces shape technical forms, that in their own influence scientific theories in continuous feedback.

The Hessen-Grossman thesis can be considered an elaboration upon a central postulate of historical materialism. Marx (1867/1981, 496-497) famously argued that *the relations of production trigger the development of the means of production*, and not the other way around. Against techno-determinism, Marx intended to clarify that it was not the steam engine to drive capital accumulation in the industrial age but rather a new economic relation between workers and capital (i.e., wage labour) which became hegemonic and required a more powerful source of energy for its expansion that had to be found in steam technology (MacKenzie 1984). Similar interpretations of technological innovations are not rare and found also in the current debates on the Anthropocene. Andreas Malm (2016), for instance, reads the adoption of fossil fuel as a source of energy in place of water similarly due to intensification of labour-capital relations in the industrial age rather than to technological agency per se. However, it is somehow symptomatic that the most accurate interpretations of labour's role in technological development are found in HST rather than in Marxist political economy and, yet, the standpoint of labour still remains a secondary perspective also in the Marxist variants of HST.

On request of the Institute for Social Research in Frankfurt, Franz Borkenau (1932; 1934; 1987) attempted to put labour at the centre of the making of modern science and its "mechanist world-picture" but he did not develop his argument convincingly. His thesis was that the abstract diagram of the division of labour would have given rise to mechanical thinking, directly, with no mediation of technology. Actually, Grossmann was commissioned his 1935 essay precisely to reprimand and amend to Borkenau's simplistic reading. In synthesis, Borkenau imagined a direct relation between labour and science (a *labour theory of science*) overlooking the epistemic mediation of technology, while Grossman framed labour, technology, and science into a more systematic scaffolding (a *machine theory of science*).

The Borkenau controversy is a reminder of a blind spot that is still under-investigated in both HST and political economy: the role of praxis and labour in shaping technoscience. To stress again such shortcoming, recently Jurgen Renn (2020) has suggested to add the *ergosphere* (the sphere of labour cooperation and knowledge production) to the world model that is usually composed by geosphere, biosphere, technosphere plus infosphere and noosphere. Within the debate on the Anthropocene, Pietro Omodeo (2022) has insisted on the level of "geopraxis" to identify the subject of collective action. And similarly, Alexandra Hui, Lissa Roberts, and Seth Rockman have proposed to initiate a *labour history of science* as a dialogue between labour history and science history,

> given the insufficiently recognized and thematized omnipresence of labor in the history of science (not to mention the lack of analytical attention given to science and its practitioners in labor history). (Hui et al. 2023, 820)

As historians of science, Hui, Roberts, and Rockman want to make the point that labour history can provide key insights to HST, but it should be noted that also HST contributed to illuminate economic dynamics, in particular regarding the role of metrics, instruments of measurement, and metrology. Practices and instruments of measurements have been always key to economic exchange, process of valorisation, the institution of money as well as labour management. Metrology has always been a political affair (Kula 1986; Schaffer 2015; Pasquinelli 2022) and the rise of industrial automation can hardly be distinguished from the practices and techniques to quantify and monetize labour.

Under this respect, Norton Wise (1988) has proposed seeing industrial technologies such as the steam engine and the telegraph, as "mediating machines", as epistemic mediators in between the domains of political economy and natural philosophy, between labour and science. Wise has stressed the twofold role of the steam engine in the measurement of labour and the making of the metric unit of work in physics (Wise 1988, 77). Wise's insight points to a common ground between value and labour in theories of automation, according to which technology is not only a *means of production* but, in fact, also an *instrument for measuring production* and labour in particular. As the Babbage principle already expressed, the division of labour (and implicitly any machine) allows the measurement and purchase of the exact quantity of labour and resources that are necessary for production. 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 once the division of labour has reached a mature stage of development (Pasquinelli 2023, 243). The metrology of labour should be used as a prism to pursue a further integration of value theories and labour theories with the standpoint theories of automation (a point that cannot be expanded here).

4. Automation theory at the times of AI

The sociotechnical composition of AI in the early 21st century provides a crucial case study and vantage point of observation, especially given the degree of automation AI has achieved in such epoch. AI is sometimes described as a novel stage of technology that would breaks from the past in terms of scale and capacity (see the myth of Singularity). But is that really so? Let's look at how HST and political economy covers the issue of AI.

HST has never considered AI (as much as its parent discipline cybernetics) as a "science", as it never deployed an experimental method to discover new laws of nature, rather an *analogical method* (or thinking per analogy) which belongs to a pre-scientific mentality. Cyberneticians believed that machines could imitate organisms (including brains), because in their view organisms were like machines. Cybernetics was a branch of electro-mechanical engineering, which was only later arbitrarily termed "computer science". As a matter of fact, the *method of AI* has always been an "imitation game" (Turing 1950) whose object is not nature, but culture – not the universal laws of the human brain to be discovered, but historical social conventions to be recorded. The Turing test came to represent this distinction. Schaffer (2024) has argued that its meaning is to demonstrate that intelligence (whatever in its mechanical or human manifestations) is and can only be an affair of *relational intelligence*, that is an issue of external conventions to follow, rather than internal (biological or logical) rules to execute.

Historians of science tend to agree that modern automated computation (from Babbage's Difference Engine to AI) has historically emerged as a measure and automation of mental labour and specifically hand calculation in the industrial milieu (Daston 1994), rather than as an artefact to simulate intelligence in the abstract. In this regard, Daston (2018) has clarified that the nature of computation (including AI) is a kind of *analytical intelligence* of human organizations and social relations that resonates with Schaffer's interpretation of *relational intelligence* in the Turing test. Internalist and cognitivist approaches in HST (Boden 2006), on the other hand, keep on reading AI as a quest to achieve "machine intelligence" in general by imitating and taking for granted "human intelligence" as an a-historical given. Contra the epistemic reductionism of certain cognitive sciences, HST has been key in clarifying that AI models and models of intelligence are historical and not universal paradigms and that both mirror social hierarchies of head and hand (Schaffer 1994).

A normative paradigm of social intelligence affects, indeed, the design of AI since its inception. The current form of AI, deep learning, originated from Frank Rosenblatt's invention of the first neural network Perceptron in the 1950s (Pasquinelli 2023, 205). The Perceptron imitated the form of biological neural networks only superficially: mathematically speaking it embodied the automation of statistical tools of multidimensional analysis that Rosenblatt, a psychologist by training, inherited from psychometrics. Psychometrics is the discipline that established the infamous cognitive test to measure the "intelligence quotient" (IQ test) and originally aimed to quantify the skills of the population by conducting statistical analyses of such tests. Embedded within the contentious legacy of Alfred Binet, Charles Spearman, and Louis Thurstone, psychometrics emerged as a branch of statistics, which has never been a neutral discipline so much as one concerned with the "measure of man", the institutions of norms of behaviour, and the control of deviations from the norm (Gould 1981). As previous forms of automation emerged from the metrics of labour within the industrial milieu, AI can be said to have emerged from the *psychometrics of labour*, i.e., the measurement and classification of cognitive skills across the population. As I stressed in another context:

> To compare human and machine intelligence implies also a judgement about which human behaviour or social group is more intelligent than another, which workers can be replaced and which cannot. Ultimately, AI is not only a tool for automating labour but also for imposing standards of mechanical intelligence that propagate, more or less invisibly, social hierarchies of knowledge and skill. As with any previous form of automation, AI does not simply replace workers but displaces and restructures them into a new social order. (Pasquinelli 2023, 246)

In short, the current form of AI, machine learning, is the automation of a statistical metric which was originally introduced to quantify cognitive, social, and work-related abilities. This is another case of the labour theory (or metric theory) of automation, as one can see how a technique to measure and organize social relations affects the design of automation itself.

The centrality of the sphere of social relations in the logical constitution of AI, rather than rationality in the abstract, is also demonstrated by its current architecture, that shows a full dependence on massive repositories of personal and collective data (Muldoon et al. 2024). Looking at the current form of AI, machine learning and specifically deep learning (i.e., the type of machine learning based on large artificial neural networks), Science and Technology Studies (STS) have made clear that such systems grow thanks and are indebted to the invisible labour and knowledge of a global multitude of workers and users (Gray and Suri 2019). Here, regarding the political composition of AI, STS prove what HST has discovered regarding its technical genealogy, that is the centrality of the labour form. In short, current AI is a type of automation technology based on the direct imitation of social relations, cultural heritage, and labour at large (both manual and mental) and in this way proving the labour theory of automation that was expounded before.

The centrality of the labour issue in AI brings us finally to consider the perspective of political economy. Although an economic estimate of the current large AI models (ChatGPT, etc.) is still difficult, it cannot be ignored that AI has already constituted powerful monopolies of information processing which can be effective in the partial automation of many jobs (Bommasani et al. 2021). However, Benanav (2020) has warned us that the perception of AI as a cause of technological unemployment may be an optical illusion and actually an effect first of global stagnation rather than automation per se (see also Smith 2020). Benanav moves from the perspective of a value theory of automation to describe AI within the financial trends of the global economy. However, see from the point of view of labour composition, AI systems such as ChatGPT appear similar to the manifestations of platform capitalism and gig economy which are actually expanding and transforming the labour market.

In the last decade, numerous offline and online activities, including small businesses, white-collar professions, care workforce, and a vast delocalised army of workers have been organized through new digital platforms that often established global monopolies in logistics, distribution, and hospitality, among other sectors (Srnicek 2016; Poell et al. 2019). What these platforms represent is not just a business model but a new pervasive form of *algorithmic* *management*, in which bosses are made redundant and replaced by software for monitoring and decision-making (Wood 2021; Woodcock 2021a; 2021b; Armano et al. 2022). The ethnography and sociology of these new forms of labour point to numerous similarities between gig economy and AI platforms: they illuminate AI systems as a new form of monopoly in the logistics and management of a global workforce (Kellogg et al. 2020; Pirina 2022; Bonifacio 2023; Peterlongo 2023). From the point of view of the information flows of the global technosphere, it appears as AI is the ultimate combination of previous processes of data collection and labour management from below rather than the invention of new powerful algorithms from above. Algorithmic management is not an "invention", rather a gradual automation of previous techniques to control and organize the workforce. As those before, also this new process of automation is not seamless, but marked by frictions and conflicts between platforms and workers. Ethnographical and sociological studies of the gig economy have revealed the antagonism that animate such platforms from within, the creative acts of disruption and hacking by workers for better labour condition and against the discriminatory practices that algorithmic management implements every day. For Bonini and Treré (2024), platform workers are continuously engaged in creative acts of "algorithmic resistance" that do not simply disrupt the "algorithmic power", but force it to adapt and innovate from within, as standpoint theories of automation also elucidated in other cases.

5. Conclusions

In conclusion, I argue that the value theory of automation applied to AI is a necessary perspective but not sufficient to explain the current state of affairs by itself. One should integrate a value theory of AI with the perspective of labour to frame AI as a technique, on one hand, for the measurement of labour and, on the other, for the control of social hierarchies, as also standpoint theory would still suggest looking at the previous centuries of technological domination. Regarding the case of AI, the analysis of the division of labour (*labour theory*) and forms of antagonism (*standpoint theory*) should help to illuminate the economic dimension of AI (*value theory*) in a better way and to understand that the valorisation process can be rarely abstracted from the materiality of living labour and social relations and that themselves cannot be removed from the destiny of the value form.

How does the internal design of AI relate to its economic dimension, that is how is its intrinsic labour form interacting with the extrinsic value form? As argued above, AI has not emerged as a specific form of automation that imitates a specific division of labour, but as a general system capable to imitate and model the most diverse forms of manual, mental, and visual labour: it represents the culmination of the labour theory of automation, the automation of the automation principle itself, or the *automation of automation* (Pasquinelli 2023b, 248; see also Steinhoff 2021). This incredible capacity of automation, however, appears to be oriented not to the full replacement of workers, rather to the automation of modular micro-tasks. The worker is not replaced by an AI system but becomes a meta-worker, or a "general worker" (a true cyborg worker, if you like), that provides the human synthesis to a myriad of micro-tasks. Each automated micro-tasks may appear as it helps and empowers the workers but actually it drowns and exhaust their overall energy. The paradox of AI is that it does not replace workers but multiple them: rather than the end of employment, it engenders *under-employment* (Benanav 2020), a precarisation of the labour market in which workers are force to work more and more. In a global tendency of precarisation and stagnation, it appears as *AI will force everyone to work more, not less*. Of course, this destiny is not inevitable. What value, labour, and standpoint theories of automation all suggest is that the technological composition of labour in a given epoch can be changed by changing its social and political composition.

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