Chapter 1

Introduction

In the second part of chapter two, this story will be analyzed in the context of the thought of Herbert Simon about computing and the organization of labor. As Babbage did, Simon knew about de Prony's project, which he read using the lens of the mid-twentieth century. In particular, he read de Prony, and he read Babbage reading de Prony, in the context of his thinking about a general mathematical science of systems. Unlike Babbage, Simon thought that machines could literally "simulate" human thinking and human actions to the point where they could replace a lot of things that humans do. Thinking in the context of a deterministic universe, Simon thought that humans are no less determined than computers in doing what they are programmed to do. Thinking that the structure of all systems is complex and hierarchical, when applied to work, Simon concedes that worker control over the production process is misguided, and I claim that this is one of the consequences of his concept of bounded rationality that is not usually discussed.

From this perspective, Simon blurred the lines between natural and artificial systems: using one to describe the other, and vice versa. I claim that this causes a very dangerous naturalization of the social, which in the context of discussion about worker control over the productive process, is perilous for democratic revindications. The fact that epistemic handicaps are used to argue for worker subordination to the bureaucratic organization is mistaken, but this is the general ontology that undergirds thinking about artificial intelligence.

My point is that to have artificial intelligence really change things for the better of workers, it is necessary to challenge this naturalization of the social. As shown in the article of the encyclopedie, technical change can free workers from toil, and free them to do other activities, but thinking that what will determine this activity, be it philosophical contemplation or delivering food on a bicycle depends not exclusively nor even mostly on the technical feasibility of the tasks in question. Rather, what this thesis sought was to show that the place and the course of technical change is also inscribed in the context of social conditions, and on the thinking about these conditions: thinking about what a worker is, and their place in society. Whatever has prevented thinking about technology within broad social context and the thinking about this context, be it a "broad church" positivism among social scientists or the idea that "facts" speak for themselves, the transformations on the future of labor by the development of artificial intelligence has to be thought about in this way. Whatever the real technical possibilities of automation due to artificial intelligence, they can only be realized by questioning also our thinking about the organization of labor, about the status of subordination within the working relations, about what it means to be a human, etc.

Chapter 2

Would You Bet Against Sex Robots?

2.1 Introduction

From the victory of IBM's Deep Blue over Gary Kasparov at chess in 1997 to the victory of AlphaGo over Lee Sedol at go in 2016, the progress of artificial intelligence (AI) in the past two decades has reignited controversies over the substitutions of humans by super computers. Does the progress of information and communication technologies (ICTs) drives us to a world in which "men are absolutely nothing", while the "king, turning a handwheel alone in an island, carries through automatons all the work of England"(Sismondi 1819, p. 330)?[1] Regarding the effects on labor, the disappearance of obsolete jobs and the alleged impoverishment of the laboring masses preoccupy the optimists in the prospects of automation (Ford 2009). The problem with contemporary debates about the automation of human activity, both lay and academic, is their naively "technicist" perspective: Could we mechanize this or that task, and at what cost? What would be the effect of increasing "computer capital" on productivity (Frey and Osborne 2013)? Can we estimate the impact on the rate of unemployment (Acemoglu and Restrepo 2018)?

2.2 The Technicist View

2.2.1 Introduction

For the purposes of this thesis, the "technicist" view is defined as the application of a realist epistemology to the question of the influence of technology on labor. This view construes *labor* as a historical and transcultural universal, whose technical characteristics are improved upon by technology; these changes are thought in terms of the technical possibilities to automatize a particular task.[2] Moreover, since jobs are understood as collections

1. My translation.
2. For a discussion of historical universals see the first two chapters of Foucault (2004).

of tasks, if all the tasks composing a job can be automatized by a firm in a cost-efficient manner, this job is then believed to disappear in the near future. I contend that many mainstream economists and many computer scientists who discuss the problem of the influence of artificial intelligence on the future of labor, be they pessimists or optimists, hold either this view or one that resembles it. Since MIT economist David Autor is one of the mainstream economists that has studied the longest the question of the consequences of automation on labor, I will analyze his paper "Why Are There Still So Many Jobs?" as an ideal type of the way mainstream neoclassical economists understand the problem.[3]

2.2.2 Body

In "Why Are There Still So Many Jobs?", Autor tries to explain the reasons for the secular high levels of aggregate employment, despite the advances in labor-saving technologies. Autor believes that focusing exclusively on job losses is misguided because understanding the relation between technology and employment requires thinking about the complementarities of different tasks with these technologies, the price and income elasticities of different kinds of outputs, and the labor supply responses. His argument is that there are certain tasks that cannot be automated but benefit from the productivity rise of new technologies. Automation, thus, complements and raises the value of jobs composed primarily of un-automatable tasks by increasing the demand for labor and raising earnings. Consequently, Autor believes that commentators often overstate "the extent of machine substitution for human labor" because they "ignore the strong complementarities between automation and labor" (Autor 2015, p. 5).

To understand how automation affects different jobs in the skills hierarchy, Autor distinguishes between two sets of tasks that have "proven stubbornly challenging to computerize": "Abstract" tasks are those placed higher in the skill hierarchy, which characterize professional, technical and managerial occupations that require high education levels, problem-solving capabilities, inductive reasoning, communication ability, expert mastery, intuition, and creativity; while "manual" tasks are those placed lower in the skill hierarchy, which characterize for the most part unskilled occupations (serving, cleaning, janitorial work, in-person health assistance, etc.) that require situational adaptability, visual and language recognition, and in-person interactions (ibid., p. 9).

Autor believes that abstract task-intensive occupations are strongly complemented by computer technologies because these enable them "to further specialize in their area of comparative advantage" by spending less time

3. I decided to present the view of an economists and not of, say, a computer scientist because contemporary society grants economists the last word on matters regarding labor.

on “acquiring and crunching information” (ibid., p. 15). Even if wage gains could be mitigated due to lower expenditures on the outputs of abstract task-intensive activities, Autor believes that evidence suggests that demand for these services has kept pace. Most importantly, workers in abstract task-intensive occupations benefit from the high barriers, such as college and graduate degrees, that require long years to prepare (i.e., inelastic labor supply).

As for manual-task intensive occupations, which hardly rely on information or data processing, Autor believes that they benefit from advances in computer technologies mostly indirectly. For example, the coupling of high income elasticity of demand for manual tasks-intensive work with rising aggregate incomes thanks to productivity growth in other areas could raise demand for manual tasks-intensive occupations. Following Baumol (1967), Autor believes that “wages in these occupations *must* rise over time” to compensate workers because otherwise they would choose a different occupation.[4] That said, Autor recognizes these wage increases will be limited by the low barriers to entry in these occupations and the labor supply increase from workers affected by automation and offshoring (ibid., p. 17).

Autor discusses these two categories of tasks in the context of “job polarization” (Goos and Manning 2003), which refers to the simultaneous growth of high-education high-wage jobs (professional, managerial, technical) and low-education low-wage jobs (low paid personal services), at the expense of middle-wage middle education jobs (skilled blue collar, clerical, sales). He finds evidence for this phenomenon in the United States, where middle-skill occupations (sales, office and administrative workers, production workers, and operatives) have declined from 60 percent of employment in 1979 to 46 percent in 2012. Citing Nordhaus (2007), he claims that the dramatic fall in the cost of computing since 1980 rose the incentives to substitute computers for human labor at the explicit codifiable tasks–which, he labels “routine tasks”—that characterize many middle-skilled cognitive and manual activities. It is precisely these tasks, Autor believes, that are increasingly performed by machines, which explains the decline in clerical and administrative support. Job polarization, however, is unlikely to erase all middle-skill jobs because, Autor conjectures, many of the tasks that compose middle skill jobs cannot be unbundled and outsourced to machinery. As a result, middle skill jobs that combine routine technical tasks and non-routine tasks where humans still hold a comparative advantage (interpersonal interaction, flexibility, adaptability, and problem solving) are likely to persist in the following decades. As for the problem of job polarization leading to wage polarization, he believes that, while possible, that trend would not continue indefinitely, except in certain times and specific

4. This claim only holds assuming that demand for manual task-intensive occupations is relatively inelastic (Autor 2015, p. 17).

labor markets.

Furthermore, citing Michael Polanyi's concept of "tacit knowledge", Autor tries to explain the difficulties in automating certain tasks. This concept refers to an alleged type of knowledge necessary to accomplish certain tasks, but whose conscious awareness is impossible for whoever possesses it–we don't know what we know. Autor, then, mobilizes this concept to explain why tasks "demanding flexibility, judgment, and common sense" have proved the most difficult to automate (Autor 2015, p. 11). Nevertheless, he acknowledges that environmental control and machine learning could bypass "Polanyi's Paradox" and, thus, facilitate the penetration of automation in heretofore untouched areas: the former by simplifying the complex environment in which machines operate, and the latter by inferring heuristic rules of conduct through data analysis–which would do away with the necessity to know these rules in advance.

Autor concludes that even though in the last few decades technology has lead to job polarization, this trend is unlikely to continue because machines raise the value of the tasks that humans uniquely provide–problem solving, adaptability, and creativity–through complementarity effects. Therefore, focusing exclusively on substitution effects is misguided. He ends the article by claiming that the economic problem of the future will be one of distribution and not of scarcity.

2.2.3 Conclusion

Although Autor's discussion raises some very important issues, it is marred by the *epistemological realism* with which he addresses the problem. Thinking about labor in realist terms–i.e., as if it existed *out there*, independently of our ideas and representations of it—

[here]

However, the limit of these studies is that they interpret the challenge of automation by artificial intelligence as simply that of estimating with a macroeconomic model the impacts of the substitution of capital for labor in employment rates, wages, etc.

My position in this thesis is that, just as Schaffer (1994) did for the analysis of automation in Victorian Great Britain, we should analyze the changes of automation not just as a question of changes in employment but as a question of changes of labor, the nature of work, and the nature of the social organization of production.

discussing many of the most important aspects regarding labor becomes impossible.

elimination of jobs by technological change as a matter of finding out whether task x can be automated at a low enough cost

As we can see from Autor's discussion, he understands the problem of the alleged elimination of jobs by technological change as a matter of finding out whether task x can be automated at a low enough cost. Appealing to the canonical mechanical analogy of the market *mechanism*, Autor finds out that although labor saving technologies do eliminate certain jobs by increasing productivity, they do not wipe out people; they just shuffle them around either at the top or the bottom of the skill pyramid. While he acknowledges that this situation might pose challenges, he is confident that the market *mechanism* will watch over those at the bottom by raising salaries in the long run to keep the janitors away from becoming doctors.

The technicist view is inadequate because

I contend that a different language that takes into account the social dimension of labor, thus, is needed.

2.3 The Historicity of the Wage Relation

2.4 Introduction

Autor's article was presented to glance at the way mainstream economists think about the impact of automation on labor. I claim that the problem with this "technicist" view is that by relying on a realist epistemology, it ignore the crucial conventionalist character of social representations and institutions. For example, the English word *work* refers to both the act of working and the thing produced, *labor* refers to work in relation to the "social question," and *job* or *occupation* refer (mostly) to the recognition of a social role by law.[5] Therefore, by interpreting a job as simply a collection of tasks, Autor ignores that jobs are codified in laws that institute certain status, rights, and responsibilities. And, as is the case for matters in jurisprudence, the issues of definitions, interpretation, and representations are crucial.

2.5 Body

To think about the conventionalist character of these social objects it is useful to mobilize Karl Polanyi's concept of fictitious commodities, which he introduced to explain how in capitalism *labor*, *land*, and *money* became commoditized. Many mainstream economists proceed to analyze the market "dynamics" of these factor of production, without inquiring about the social conditions of possibility that have granted them their status as commodities. For example, when Autor claims that "the elasticity of labor supply can mitigate wage gains", one must wonder, why there is a labor supply at all. Contemporary economic analyses takes for granted that there will be people willing to work for a wage, but as studies of labor in ancient Mesopotamian society have shown, getting others to work for

5. These definitions are provided in loose form precisely to highlight their polysemy.

one's account is an extraordinarily complex matter (Steinkeller 2015, p. 5). In fact, Steinkeller shows that in bronze age Mesopotamia, the problem was often lack of population to cover all work needs (demanded mostly by the palaces and temples) and not, as it is today, *unemployment* (ibid., pp. 9–19). The reason is to be found in the social and institutional configuration, in which most of the peasant citizenry was not alienated from their means of subsistence–specifically, arable land. By linking citizenship to landownership, Mesopotamian institutions secured for the peasantry a certain independence from both public authorities and potential "employers." Except for the annual corvee labor provided as is today's military service–a mostly non-remunerated public duty–, the peasantry had few incentives to work for others, when they could rely on themselves and their households.[6]

Another example of the conventionalist character of labor is the origins of the work contract. Despite their contemporary ubiquity, the work contract is a very recent institution, even in Western civilization. As Supiot (2016) shows for French Civil Law, the ancestor of the modern work contract (*contrat de travail*) is a lease agreement (*contrat de louage*), whose origins lie in the Roman *locatio operarum.* Supiot claims that, regarding the *locatio operarum*, Roman Law reasoned in analogy to the institution of slavery: Since freemen sold the products of their labor but not *their* labor, the destitute who worked for the account of others were thought to lease themselves (*locat se*) as if they leased their slave (*locat servum*) (ibid., p. 8). Following the introduction of the principles of freedom of business (*liberté du commerce*) and freedom of industry (*liberté de l'industry*) to work (*travail*) by the Decree d'Allarde (16 February 1791), the French civil code assimilated the labor relation to a type of lease. As for the phantasmic object of the work contrat–Is it the *worker*? Is it the *work*?—, Supiot claims that the possibility to contractualize work derives from the application of the concept of property (*patrimoine*) to the relation of *work* to the worker: Since work is the private property of the worker, he has the right to freely dispose of it on the market (Supiot 2011, pp. 45–66).[7]

As these examples show, the social conditions that push a majority of the

6. Regarding the importance of corvee labor in ancient Mesopotamia and ancient Egypt, Hudson remarks that the "Hollywood" image of slaves building the pyramids under the scorching sun and the whip of the overseer is mistaken, for the majority of the labor needed to build these infrastructures was provided by semi-free labor. He claims that although slaves and other dependents *did* exist in these societies, they were never numerous enough to provide the necessary labor requirements (Hudson 2015, p. 649).

7. This discussion provides only an intuition but not an accurate description of the significance of these terms in the context of the jurisprudence. Aside from my lack of competence, the differences between Civil Law and Common Law compound the difficulty of discussing these terms unambiguously since they are not equivalent across legal systems. As an example of the challenge of cross country comparisons in the European Union, Supiot remarks that even the concept of work contract differs from country to country (Casas et al. 2016).

population to sell their labor in exchanges for wages beg an explanation. These social conditions are what french sociology of work (*sociologie du travail*) calls the *salariat* (the institution of wage earning). I content that the *salariat* is often elided in mainstream economic analyses of the influence of technology on work, but the kernel of the problem of automation is that of the place that humans will have in that vision of the world and the transformation of the social conditions of production. An analysis in terms of the concrete tasks that can (or cannot) be automated, then, misses the point. This is not to deny that the technical component of new technologies and specifically artificial intelligence is crucial, but to advocate for the inscription of these debates within broader legal, social, and political issues. Thinking that technological changes will simply do more of the same but faster, while people are moved around as potatoes by the caprices of the job market is both naive and wrong. Technological change has to be understood within broader cultural and historical trends. Taking into account this polyphony allow thinking about the role of ideas, institutions, and social representations in paving the way for the introduction of these technologies and their applications in the workplace.

I do not deny that one day machines might govern, but this would result not from a coup as in the 1984 movie *Terminator*, but from voluntary regime change. As recent discussions of the replacement of judges by algorithms show, the issue is not simply one of the technical prowess of machine intelligence, but rather one of our own understanding of what constitutes the "production" of justice: If the work of a judge is simply to process an input–i.e., a case–and compare it to an existing body of law, it is not far fetched to imagine a textometry algorithm don the gown and the wig in the near future. But, this automation of justice depends on our *convening* about the right way to produce justice. Undeniably, ICTs will facilitate data retrieval, and this will hopefully help judges be better judges and doctors be better doctors, but the question of the complete replacement of these jobs by machines is not only a technical but a conceptual question about what this jobs are actually about. Otherwise, we risk creating dangerous sociotechnical systems such as those of the 1964 movie *Dr. Strangelove*, in which control of the missile defenses of the United States and the Soviet Union are automated to erase human error, resulting in the escalation of nuclear war due to their "efficient" retaliation capability out of human control. It may come the day when we are governed by machines, but this will be a consequence of our convening that they have the right to govern.

2.6 Conclusion

However, the limit of these studies is that they interpret the challenge of automation by artificial intelligence as simply that of estimating with a macroeconomic model the impacts of the substitution of capital for labor in employment rates, wages, etc. My position is that this way of framing and analyzing the problem is not very interesting and offers very little insight on the wider issue of the changes portended by artificial intelligence.

My point of view is that many of the various analysis on this matter are marred by their narrow scope that only focuses on the possible impact of new technologies on what economists call macroeconomic varibales. Briefly put, the views of neoclassical or mainstream economists, whether optimists or pessimists are decided on whatever the economist thinks that the impact of these technologies will be on macroeconomic variables such as investment, consumption, employments, wages, etc.

Chapter 3

Did Adam Smith Invent the Digital Computer?

3.1 Introduction

On November 14, 1957, in an address to the Twelfth National Meeting of the Operations Research Society of America, Herbert Simon advanced the provocative proposition that "physicists and electrical engineers had little to do with the invention of the digital computer", for "the real inventor was the economist Adam Smith, whose idea was translated into hardware through successive stage of development by two mathematicians, Prony and Babbage." (Simon and Newell 1958, p. 2). This provocative statement was no less controversial then, but is it accurate?

After establishing, in chapter one, that the technicist view ignores the historical specificity of the concept of labor, in this chapter, I sketch a history of the relation between thinking about the possibility of intelligent machines and thinking about the organization of labor to show how they have been related in the thought of Charles Babbage and Herbert Simon. The reason for focusing in these two authors is that Babbage's construction of a machine called the Analytical Engine is considered retrospectively by computer scientists to have been the first programmable computer. As for Simon, he is famous not only as the 19XX Nobel prize in economics and a great theoretician of administrative science, but also as one of the founders of the discipline of artificial intelligence. The way this history will be sketched is by analyzing the importance of the project for the calculation of the logarithmic tables by de Prony by two pioneers in the history of the computer: Babbage and Simon. The division of labor as embodied in the allocation of tasks in de Prony's project shows, the first large *computing* project was not only a project that showed the efficiency of the distribution of mental labor, but a new form of subordination of the mind to a particular organization of mental work in which workers were not only deprived of control but of full knowledge over the productive process.

3.2 Manufacturing Logarithms

3.2.1 Body

Gaspard Clair Francois Marie Riche de Prony (1755–1839) was born in Chamelet in the Beaujolais region of Southern France to a family of the provincial middle bourgeoisie–the social class that would fill the ranks of the Revolution and Empire's bureaucracy (Picon, Chicoteau, and Rochant 1984). After an education in the Classics, in 1776, at twenty-one, he entered the École des ponts et chaussées in Paris. Prony's life coincides with a period of the institutionalization of French sciences and techniques with the foundation in 1794 of the École polytechnique–where he was appointed professor of analysis and mechanics with Joseph-Louis Lagrange–and the École normale supérieure. Moreover, this was a time of growing interest among the savants for applied problems, and the generalization of the application of mathematical formalisms.

Following the French Revolution, the recently constituted Assemblée nationale decided in 1790 to replace the ancient taxes by a land tax (Peaucelle 2012, p. 6).[1] Therefore in 1791, the Assemblée founded the Bureau du Cadastre, with de Prony as director, to conduct a land survey that would draw the boundaries of landed property in every French commune.[2] In connection with this plan, the revolutionary government decided that a very large set of logarithmic and trigonometric tables would be produced to supplement the decimal-based metric system. This was necessary because the traditional sexagesimal division of the circle–now regarded as quaint and irrational–was replaced by a decimal division, which rendered obsolete the older trigonometric tables used by geodesists and astronomers.[3] So it fell upon de Prony to direct a project to calculate and print these tables.

De Prony estimated that even with the help of three or four skillful collaborators, the rest of his life would not suffice to finish the calculations needed for the tables. One day in front of a book shop, he spotted "the beautiful English edition" of Adam Smith's *Wealth of Nations* (Anonymous 1820, p. 7). As he opened the book haphazardly, he stumbled upon chapter one, where Smith discusses the manufacture of pins, and, suddenly, he conceived the idea to apply the division of labor to the production of the Cadastre tables "to manufacture logarithms as one manufactures pins" (Riche de Prony 1824, p. 35).[4] Drawing from his lessons at the École centrale des

1. According to Peaucelle (2012), the assembly was inspired in this regard by the ideas of physiocratic economist François Quesnay.

2. Although the Cadastre's initial objective was to assist fiscal policy by levying land taxes, under Prony's direction, the production of maps and statistical tables took precedence (ibid., p. 76).

3. The decimal division of the circle along with the decimal division of time were later removed from the metric system (Daston 1994, p. 184).

4. My translation.

travaux publics (later École polytechnic) on the applications of the method of differences to interpolation, he conceived a plan to break up the calculation of the final values of the Cadastre tables into a long series of simpler steps. By using logarithms to simplify complex operations into additions and subtractions, these simplified operations could be calculated even by a hairdresser familiar with only the most rudimentary arithmetic. De Prony, thus, organized the calculation of the tables by dividing the Cadastre employees into three sections, following a hierarchy of skill: At the apex, the first section comprised five or six eminent mathematicians who carried out the analytical part of the work by choosing the mathematical formulae and the initial values of the angles. The second section comprised seven or eight "calculators", with knowledge of both arithmetic and mathematical analysis, who derived from the formulae of the first section the values of the initial logarithms and the initial differences of various orders.[5] They also prepared the folio sheets used by the third section "by laying out the columns of the chosen values and the first row of entries" (Grattan-Guinness 2003, p. 109). Furthermore, they wrote on the page the instructions to be followed by the third section and verified their calculations. At the base, the third section comprised between 60 and 80 calculators who only carried out the additions and subtractions of the intervals between two numbers, as chosen by the second section. Prony remarked that "those who knew more [arithmetic] were not always those subjected to less errors" (Riche de Prony 1804, p. 53).[6] The calculation of the tables began in 1793, and although the core of the project had been completed by mid-1796, verifications took a few more years, so that the project was finally completed "at the end of the 1790s or the beginning of the 1800s" (Roegel 2011, p. 37).

Despite the novel rationalization of the organization of labor that it promoted, the project of the Cadastre tables was isolated among French productive activities, which remained mostly artisanal. It was intended as a "monument" to rationality and not a mass produced commodity (Riche de Prony 1804, p. 57). If the thorough industrialization of French production

5. At this time, in both French and English, calculator (*calculateur*) referred not to a calculating machine, but to a job.

6. In his famous article "Work for the Hairdressers", Grattan-Guinness claimed that "[m]any of these workers were unemployed hairdressers", but this affirmation, although now widespread, has elicited controversy (Grattan-Guinness 1990, p. 179). Roegel (2011), who has closely studied the lists of the employees at the Cadastre, disagrees with Grattan-Guinness's emphasis on the employment of hairdressers because he suspects that "there were only two or three of them" (ibid., p. 26). Nonetheless, Roegel acknowledges that the first mention of the hairdressers seems to be an 11th November 1824 discourse by engineer Charles Dupin–Prony's close friend— from which Grattan-Guinness drew upon (Dupin 1824). Moreover, Roegel claims that the number of computers employed probably never exceeded 20 or 25, so Prony exaggerated his figures. See Roegel (2011), p. 27, footnotes 96–98). Indeed, a contemporary witness estimates them at about fifteen (La Lande 1803, p. 744).

would have to wait until the twentieth century, the tables project was an early example of the application of the engineer mentality to the organization of labor. This is evidenced in its application of the division of labor to a hierarchical organization of skills. At the time of de Prony, even if attitudes towards the *mechanical arts* had been changing beginning in the ninth century (Vatin and Pillon 2007, p. 10), these were still associated with low ranked repetitive labor devoid of intelligence.[7] Discussing the workers of the third section of the tables project, the famous nineteenth century French engineer Charles Dupin remarked that they "ended up blessing the change that removed them from hard work, to devote themselves to occupations that called upon the use of thought" (Dupin 1824, p. 211).[8] Nevertheless, according to Daston (1994), by pooling the talent of mathematical genius with the brute force of mindless calculation, de Prony's project contributed to demote calculation to the lowest of mental faculties. In fact, until the mid-nineteenth century, in both French and English usage, *work* and *mechanical* were associated by referring to the laboring body, so that mechanizing calculation degraded this activity from its previous status as a manifestation of mathematical gifts.[9] In this regard, Daston considers that de Prony's project is a landmark in the history of intelligence because "it pushed calculation away from intelligence and towards work" (ibid., p. 190).

3.2.2 Conclusion

If the mechanization of intelligence began with de Prony's project, its contemporary significance as precursor to the development of the programmable computer comes from Charles Babbage, who knew about the project and used it as inspiration to design a series of powerful mechanical calculators: the Difference Engine I and II, and the Analytical Engine. Even though Babbage was

Babbage is remembered today as the inventor of the Analytical Engine, which is referred as the first programmable computer.

7. In this regard, Friedmann cites the ambivalence in the *Encyclopédie* of the definition of *artist*:"we say of a good chemist that deftly performs the procedures that others have invented, that he is a good artist, with the difference that the word artist is always a praise in the first case, whereas in the second, it is almost a reproach of only possessing the subordinate part of his profession" (Friedmann 1953, my translation, footnote 1, p. 55).

8. My translation.

9. As an example of the importance of calculation, the German-Dutch mathematician, Ludolph van Ceulen (1540-1610), devoted long years to the calculation of π to thirty-five places. This was considered such an accomplishment that π is sometimes referred to in German as Ludolph's number (*Ludolphsche Zahl*) (Maor 1994, p. 50).

3.3 Weaving Algebraical Patterns

Charles Babbage (1791–1871) was born in Walworth, Surrey close to London, at a time, when the capital was the commercial and industrial center of Great Britain. Although he never secured an employment for very long, he inherited a large estate from his goldsmith turned banker father, which allowed him to pursue his scientific interests more-or-less independently of financial constraints. Babbage was one of the eminent nineteenth century Romantic gentlemen scientists,[10] joining numerous clubs and societies to advocate the application of science to different domains. For example, he co-founded the Analytical Society (1811), the Royal Astronomical Society (1820), the British Association for the Advancement of Science (1831), and the Royal Statistical Society (1834). During his life–and even today–he was regarded primarily as a gifted mathematician, graduating from Cambridge in 1814, and becoming there professor of mathematics in 1828.[11] In fact, one of his most important contributions is the introduction of French "abstract" mathematics to Great Britain.[12]

At some point, in the year 1820 or 1821, the Astronomical Society appointed a committee consisting of John Herschel and Babbage to prepare statistical tables for astronomical calculations. One evening, while the two men were tediously verifying the numbers produced by two hired "computers," Babbage exclaimed that he wished "we could calculate by stem." And, this was Babbage's own account of his source of inspiration for the construction of a series of calculating machines to automate the production of statistical tables, the first of which was called the Difference Engine.[13] This machine derived its name from the method of differences discussed earlier, which Babbage had *translated* into mechanism through a complex system of wheels and gears. The Difference Engine was a massive and heavy machine that received its "input" by setting the initial values on the toothed number wheels, which were, then, activated by a human turning a crank.[14]

After completing a working model with six figure-wheels in 1822, he

10. This figure would disappear with the advent of twentieth century Big Science: massive personnel, lavish government budgets, and hierarchical organization. See Mirowski (2011).

11. According to Romano, Babbage never moved to Cambridge nor ever deliver a lecture there as professor of mathematics (Romano 1982, p. 387).

12. One of the likely reasons for Great Britain's resistance to Continental advances in mathematical abstraction was the priority debate over the discovery of the calculus between Newton and Leibniz. According to Maor, this controversy discouraged the introduction of the Leibniz's notation in Great Britain. See Romano (ibid.), chapter 9.

13. Although the most widely known are Babbage's Difference Engines (I and II) and the Analytical Engine, he had plans for more calculating machines.

14. The machine consisted of several parallel columns of rotating piled up toothed number wheels. Each column containing n wheels could represent a number with $n-1$ decimal places.

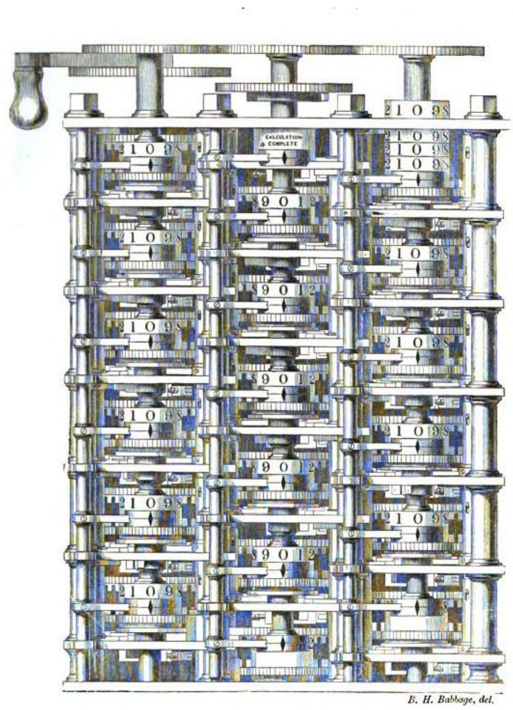

Figure 3.1: Section from the Difference Engine I as assembled in 1833 (Source: Wikipedia).

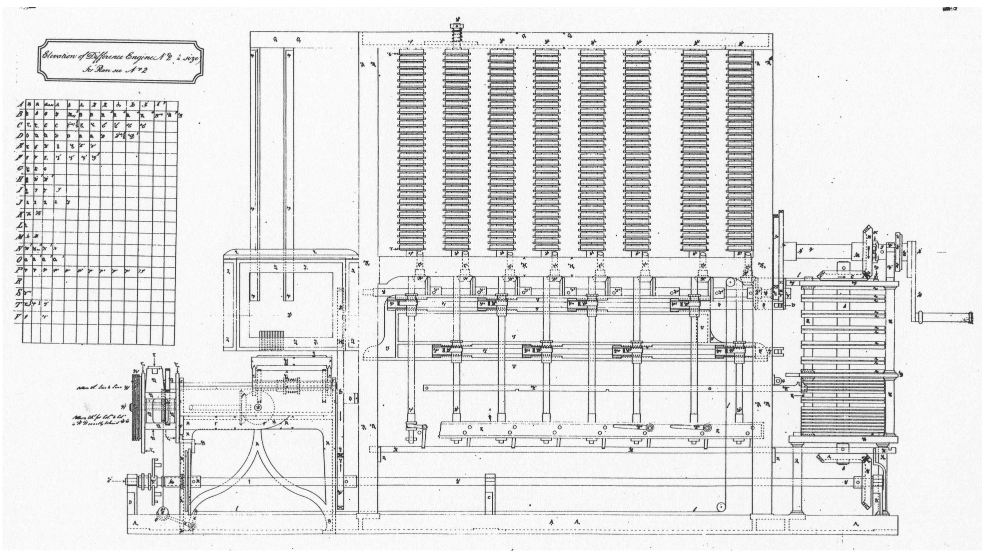

Figure 3.2: Difference Engine II Diagram (Source: Wikipedia).

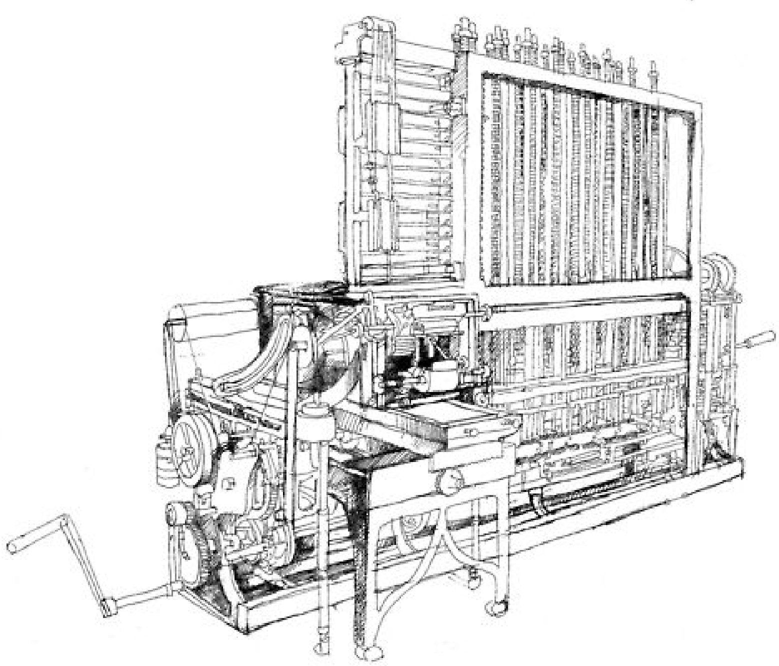

Figure 3.3: Difference Engine II Drawing (Source: Wikipedia).

published an open a letter to Sir Humphry Davy–then President of the Royal society–to secure government financial assistance. In this letter, Babbage sketches for the first time the concept of the *mental* division of labor, citing de Prony's tables project as evidence of the possibility to mechanize calculation. Babbage explains that the third section of de Prony's project, whom "the most laborious part of the operations devolved" (Babbage 1822, p. 214), could be reduced in number of employees to only twelve by the use of calculating machines: their labor would be to copy the numbers displayed by the Engine's wheels.

> The intolerable labour and fatiguing monotony of a continued repetition of similar arithmetical calculations, first excited the desire, and afterwards suggested the idea, of a machine, which, by the aid of gravity or any other moving power, should become a substitute for one of the lowest operations of human intellect. (ibid., p. 212)

As this quote shows, Babbage believed that de Prony's project incorporated a hierarchy of tasks, of which calculation was the paradigmatic mental operation that required the least application of intelligence. If Daston (1994) is correct, the association of mechanism with the laboring body of low-skilled low-paid laborers was the main factor behind the loss of prestige of calculation. Daston's claim is important because there is an "economic" tendency to explain away this change in status by appealing to *scarcity* and the *laws* of supply and demand, but this argument is misleading. Despite all the rhetoric, should Babbage's machine been completed, it would have most likely been used by large organizations (as was the case with the first mass-produced electronic computers in the twentieth century), for, as Maas argues, its sheer size rendered it impractical for most everyday scientific applications (Maas 2005, p. 103).[15] Instead, the Engine contributed to shape the nineteenth century ideas in Great Britain about intelligence by showing that what had been thought to be the prerogative of the mind could be accomplished by mechanism. It was, thus, the lack of social prestige of mechanism–and its association with the low class of citizens that would soon become the proletariat–that undermined the social status of calculation.

Another important aspect of Babbage's work, with major implications for the construction of his Engines, was his famous book *On the Economy of Machinery and Manufactures*, which consecrated him as an expert on industrial production techniques. As he constructed the Difference Engine, Babbage was forced to turn his attention to the study of machinery and manufactures because of the precision engineering required to produce the tolerance levels of the Engine's pieces. After the death of his wife in 1827, Babbage embarked on a long tour to study Europe's best methods of production, and, back in England in late 1828, he began working on his famous book on manufactures. The book, published in 1832, discusses de Prony's project as if resembling a British cotton or silk-mill, thereby drawing a close analogy not only between mental labor and bodily labor, but between calculating machine and manufactory.

> When it is stated that the tables thus computed occupy seventeen large folio volumes, some idea may perhaps be formed of the labour. From that part executed by the third class, which may almost be termed mechanical, requiring the least knowledge and by far the greatest labor, the first class were entirely exempt. ...when the completion of a calculating engine shall have produced a substitute for the whole of the third section of computers, the attention of analysts will naturally be directed to simplifying its application, by a new discussion of the methods of converting analytical formulae into numbers. (Babbage 2009, p. 157)

Two years after the book's publication, Babbage began drafting plans for a more ambitious calculating machine: the Analytical Engine, the pre-

15. During Babbage's lifetime, only functioning sections of the Engines were produced, but not a single one was completed in its entirety. In 1991, a group of researchers constructed a full size Difference Engine II to prove that such a machine could be built using the materials and engineering tolerances available to Babbage. See Swade (2000).

cursor to the modern programmable computer.[16] Unlike the Difference Engine, which was limited to one operation, the Analytical Engine could be *programmed* by the use of three types of punched cards–Variable cards, Number cards, and Operations cards–to perform any series of the four basic arithmetical operations. Maas's claim that the "Analytical Engine incorporates in its design the architecture of a factory" is not rhetorical flourish (?), for this new mechanical computer was literally modeled after the large scale division of labor of English industry and de Prony's project. Specifically, the Analytical Engine consisted of several logical sections, the most important of which were the memory, the *Store*, and the central processor, the *Mill*. As their names imply, the Store was responsible for "storing" numbers until they were required (as indicated by the Variable cards) to be "milled" at the Mill. Translated in mechanical terms, this means that the Store kept a number–represented by the positions of the piled up toothed wheels in a column–which was transferred to the Mill when called upon by a calculation. Every operation, from number input (Number cards), to ordering the sequence of operations (Operations cards), to number conveyance across the Engine (Variable cards), was controlled by the three types of punched cards: These were fed to the Engine as long series of tied up cards that activated the various levers, which in turn, turned the wheels. What this short description of the *workings* of the Analytical Engine tries to show is that Babbage's analogy with a silk mill was not a mere pedagogical expedient but a reference to the working principles of one object to understand the functioning of another.[17] In this regard, it is noteworthy that Babbage borrowed the idea to use punched cards to *command* the Engine from the Jacquard loom: A weaving machine that threaded complex patterns in fabrics by following the instructions codified in the punched cards. These cards were fed into the loom in long series, which activated a system of levers that threaded the codified pattern. It was, then, in the context of

16. Babbage's Engines were forgotten and then rediscovered in the middle of the twentieth century, most notably by Howard Aiken, inventor of the Harvard Mark I. See Staff of the Computation Laboratory (1946), Introduction. Nevertheless, the influence of Babbage in the development of the twentieth century electronic computer is only retrospective. I surmise that despite the long history of calculating machines, between Leibniz's *Staffelwalze* in the seventeenth century to ENIAC in the mid-twentieth century, the influence of most of these inventions to the development of modern computers is, unfortunately, only retrospective historical reconstruction.

17. Understanding the history of any science requires the identification of the analogies that become engines of discovery for a period of time. These analogies shed light over certain aspects of an object, while obscuring others. They may also carry along other habits of thought from one realm into another. In the transition from mechanical to electronic calculation, the *human mind* superseded the *factory* as the analogy used to understand the workings of the machine. This change of analogical referent had profound consequences for twentieth century behavioral sciences, which, building on the nineteenth century neurophysiological reductionism of mind to brain activity, understood the human mind to be a mechanism akin to an electronic computer, and vice versa

analogies between factories and calculating machines that Babbage's friend Ada Lovelace wrote that "the Analytical Engine *weaves algebraical patterns* just as the Jacquard-loom weaves flowers" (Lovelace 1843, p. 25).

From the point of view of the social significance of technology, the Analytical Engine was important because, if with its predecessor, the Difference Engine, thoughts on machine intelligence were blue sky speculations, the new machine, with its more sophisticated automated systems, elicited discussions about the possibility that it was able to think–or, at very least, to reproduce those "lower operations of the human intellect." For example, whereas one Italian engineer who corresponded with Babbage assured that "the machine is not a thinking being, but a simple automaton that performed according to the laws that one has traced for it" (Menabrea 1842, my translation, p. 358), Ada Lovelace claimed that:

> It were much to be desired, that when mathematical processes pass through the human brain instead of through the medium of inanimate mechanism, it were equally a necessity of things that the reasonings connected with *operations* should hold the same just place as a clear and well-defined branch of the subject of analysis ... (Lovelace 1843, p. 22)

Although Lovelace's interpretation was probably rare at the time, her identifying intelligence with operations that could be carried out in different "hardware" proved important from the point of view of the history of intelligence because she drew a parallel between logic, mechanical operations, and the operations of the mind. This same idea would surface with the publication in 1954 of George Boole's *Laws of Thought*, in which he presented Boolean algebra, not just as an abstract theory of logic, but as a psychological theory of the operations of the mind.

What is curious is that this discourse about machine intelligence is contemporaneous to the submission of a whole class of citizens to the factory system, the wage form, and the contractualization of labor relations. As Schaffer (1994) argues, these concerns were central to the manufacture of the Engine's pieces with the right tolerance levels because their production required not just more precise tools, but also a reconfiguration of the social space of production. Specifically, the production of Babbage's Engines accompanied not only the introduction of advances in machine tools and engineering techniques, but the disembodiment of the ownership of skills that had been the property of workers. For example, the newly introduced automatic lathes could produce more precise pieces, but their operation implied both a re-training of workers to watch over the machine and a loss of skill, which was traditionally recognized as the property of the worker (ibid., p. 214). The automatic tools appropriated and incorporated the skills of the workers. In this regard, Schaffer interprets Babbage's 1832 book on manufactures as a work of industrial intelligence to wrest off technical knowledge from workers, to be appropriated by Babbage as a kind of proto-manager. This knowledge was then mobilized to build the tools and the workshops were the Engine's pieces would be produced. As Schaffer mentions, in Babbage's London, tool manufacturing followed certain customs regarding production techniques, "intellectual property", and control and authority over the production process. The "technical" advances required for producing the Engines were not innocent, in Schaffer's interpretation, because both the discourse about the organization of work and the social relations of production had to be transformed for the construction of the Engines to be possible. Among the changes Schaffer cites, we can mention the dispute over the property and the rights over the automatic tooling to produce the pieces of the Engine, which were traditionally owned by master engineers, and the relocation, at Babbage's behest, of the workshop to his house (to have greater control over the surveillance of production). As Schaffer argues, the "philosophers of machinery" promoted rational valuation of work to render the labor process transparent, and skill measurable and thus payable according to a wage set in a marketplace. In other words, my interpretation is not that there was duplicity in the intentions of the "philosophers of machinery", but a genuine belief that the submission of workers to machinery was good because it promoted the application of reason to social organization. Workers *seemingly* vanished from the production process of the new thinking machines. As machines became better at mechanical and mental tasks, workers were subordinated as appendices to these machines. They never disappeared but became invisible.

3.4 Conclusion

To answer the question in the title of this chapter: No, Adam Smith did not invent the electronic computer, in the sense that he wasn't involved, even indirectly, in its development. One common misconception about Smith's concept of the division of labor is that he is talking primarily about machinery. But, this is an anachronistic interpretation because what Smith had in mind was a technology for the organization of labor that would raise productivity.

Chapter 4

Conclusion

For example, will the masses of unemployed drivers become part of government job-guarantee programs Wray 2003 that will in turn put more pressure on private sector businesses to improve working conditions? Will the government instead opt to provide incentives to the private sector to create replacements jobs while providing a basic income to those unable to be profitable employed by private enterprise? Will this new class of state dependents become a pariah class that threatens social cohesion? I think these are the questions that artificial intelligence really brings to the fore. For as Mirowski (2011) claims, there has been a very big change in the social organization of American science since the end of the second world war, passing from a state-led to a private firms-led model of funding and organization of science. And, if there is one area where this is most obvious is in artificial intelligence, where big tech giants such as Google and Facebook are responsible for directing some of the most important research projects in this domain.

The next step is to link with Herbert Simon, who as founder of the discipline of artificial intelligence .

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