Whither the evolution of the contemporary social fabric? New technologies and old socio-economic trends

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Abstract. *This article considers whether societies are witnessing another industrial revolution in the light of an assessment of the impact of technological change on today's socio-economic fabric, especially with respect to employment, income distribution, working conditions and labour relations. The authors argue that the processes of innovation and the spread of what they term "intelligent automation" are likely to exacerbate incumbent patterns of uneven income distribution and power, some of which existed well before the arrival of the technologies concerned, while others have emerged over the past 30 to 40 years. They venture to consider policy implications on the basis of such developments.*

> The first man who, having enclosed a piece of ground, bethought himself of saying "This is mine", and found people simple enough to believe him, was the real founder of civil society.
>
> J.-J. Rousseau, 1755, p. 109

The reflections in this article build on two interrelated questions that have been of great concern to us and to many other observers of contemporary socio-economic transformations,[1] namely, whether we are witnessing another "industrial revolution", and the impact of technological change on the current socio-economic fabric, especially with respect to employment, income distribution, working conditions and labour relations. We could take the easy reductionist road and fall back on the economist's standard repertoire of production

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[1] For further discussion see, inter alia, Franzini and Pianta (2015) and Milanovic (2016).

function, proxies for changing skills, and labour supply and demand, to come up with a ready answer: in the long run, the system will self-adjust to a new equilibrium, with all unemployment being merely frictional or voluntary and pay rising for those who perform the tasks required by the new technologies and falling for workers whose tasks can be replaced by machines. This last group is in fact partly to blame for not satisfying market demands and should retrain.

In this article, however, we take a different approach. We go back to the basics, addressing the coupled dynamics of technological change and socio-economic development at intertwining levels of analysis. We believe that, before assessing the impact of new technologies, we have to examine pre-existing trends in income distribution, labour relations and industrial structures. Then, we have to assess the nature and impact of technologies, old and new, in their own right before plugging them into a relatively far-fetched, history-invariant economic model. Those new and old technologies are nested in complex political economies, at all levels of analysis, ranging from the division of labour and power at enterprise level to legislative, fiscal and demand-management policies. Lastly, we have to gauge the impact – no matter how strong – of technological and institutional changes in a much broader light than that of per capita GDP growth rates alone. For example, welfare and working conditions, equality of opportunity, social mobility and quality of life are just as, if not more, important. In our view, we are currently facing a historical paradigm shift in which the long-term patterns of the future will be shaped by the socio-economic structure, power relations and policies of the present.

Arguably not since the First Industrial Revolution has competition between humans and machines and its impact on working conditions painted such a bleak picture, especially when coupled with the explosion of rent-seeking behaviour and the risk of social exclusion characteristic of today's globalized and financialized economy. What can we learn from the past? Historians are quick to point out that these concerns, far from being unique to this age, have characterized all industrial revolutions, all of which dramatically changed the relationship between machines and human labour. On the one hand, new technologies threaten established ways of doing things, working conditions and employment patterns; on the other, they provide new opportunities for economic growth and social change – so much so that, in the long run, technology has proved a formidable engine of growth and led to substantial improvements in living conditions. Emergent technologies can foster new business opportunities and enable effective solutions in areas of application that existing technologies are unable to cope with. Sectors such as medical services and health care, for example, where costs are increasing rapidly and disproportionately, can derive enormous benefit from the adoption of new technologies, provided those in need have adequate access to them.

Similarly, at the macroeconomic and societal levels, to paraphrase Chris Freeman, new technologies may herald an "economics of hope", with work for all and equitable social inclusion, or, conversely, mass unemployment, mass inequality and social exclusion, leading to a "re-feudalization" of Western societies (Freeman, 1992; Freeman and Soete, 1994). In both scenarios, it is not the

technologies as such that are good or bad; it is the social and economic factors that are crucial as new dominant paradigms emerge and start to be adopted.

Today, we have a rare historical window of opportunity collectively to "choose" where we are heading in terms of constellation of paradigms.[2] There are two extreme archetypes. The first we will call the *Blade Runner* scenario – after Ridley Scott's 1982 science fiction film: it consists of a sort of techno-feudalism in which a highly sophisticated but tiny ruling class exists alongside an enormous lumpenproletariat of very intelligent but largely obedient people enforcing power and income distribution in favour of the rich and powerful. Indeed, one drawback of the aforementioned film is that it does not portray an even more extreme scenario: a class of ignorant and greedy rentiers sharing power and wealth with the techno-feudal class, and a lumpenproletariat basically made up of almost subhuman slaves without citizenship or rights.

At the opposite extreme, the alternatives range from Keynesian (1931) progressive and liberal proposals that remain within the scope of capitalist society, to the *Communist Manifesto*, which advocates the reorganization of entire societies based on the Marxist creed "from each according to his ability, to each according to his needs". Under this archetype, new technologies will free people from boring, degrading and alienating work and enable them to spend most of their time at leisure, playing, satisfying their curiosity, learning and enjoying life. We are now in a position to consider this a workable utopia, at least in developed economies.[3]

Be that as it may, the processes of innovation and spread of what can be termed "intelligent automation" are likely to change, and most likely reinforce, the uneven patterns of income and power distribution that existed well before the arrival of the technologies discussed here; indeed, some of them have been intrinsic features of capitalism since its inception, while others have emerged in the last 30 to 40 years. Technologically, elements of paradigmatic discontinuity exist alongside more incremental change. What is new about the current technological transformations is the "intelligent" use of big data to exercise control over the social sphere without, apparently, a comparable paradigm shift in the use of "Industry 4.0" technology or devices vis-à-vis the previous ICT-based automation of production (Moro et al., 2019).

The remainder of this article is organized into six sections. In the first, we take a vast ensemble of secondary evidence to paint a picture of certain trends that certainly preceded any potential "Fourth Industrial Revolution" but will be amplified by it, in line with our concept of "rentification of capitalism". In the second section, we discuss the features of a possible new techno-economic paradigm, distinguishing between Industry 4.0 and the more pervasive impact

[2] Techno-economic paradigms consist of a constellation of micro-technological paradigms as defined by Dosi (1982) (e.g. semiconductors, electronic computing, etc.) that have a pervasive impact on the entire economy as discussed by Freeman and Perez (1988).

[3] For developing economies, this is still a far more distant goal: much technological and organizational learning, together with demographic control, lies ahead. Qualitatively, however, the choice between the two archetypes applies at all levels of development.

of big-data analytics on social reproduction. The third section examines the relationships between technology, productivity and growth, while the ensuing impact on employment is discussed in the fourth. In the fifth section, we consider patterns of division of labour, distribution of knowledge, power and control in the era of rentified capitalism before we address a number of policy implications in our concluding section.

Some broad trends

Economic growth is broadly understood to be uneven. This applies across countries and also across social groups and classes within countries. The Industrial Revolution possibly entailed the biggest explosion of such disparities in human history, even greater than the split between agricultural societies and hunter-gatherers thousands of years earlier (Dosi, Freeman and Fabiani, 1994; Freeman, 2019). Our primary concern here, however, is what happens in industrial societies characterized since their take-off by persistent technological change leading to exponential growth in labour productivity. In this respect, the relationship between productivity and wage dynamics is crucial.

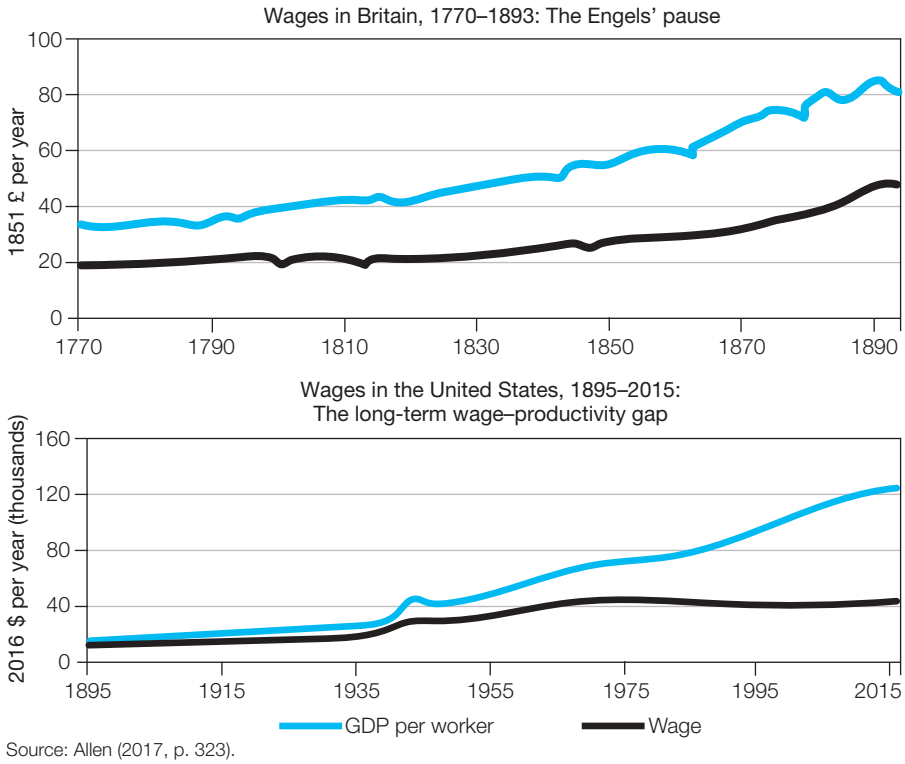
In aggregate terms, the relationship between productivity gains arising from new technology and wage growth goes through alternate phases. During the First Industrial Revolution (1770–1830), wages almost stagnated and started to rise only as of 1830, approximately 60 years after per-worker output began to increase; Allen (2009) calls this "Engels' pause" (figure 1). At the same time, the entire subcontinent of India was forced into "early deindustrialization" and mass starvation. A much tighter link between productivity and wage growth characterized the "Western ascent to affluence" (1830–1970), according to the periodization proposed by Allen (2017). However, a new phase of decoupling started in the 1970s and has continued ever since – Allen calls it the "problem-ridden present" (figure 1).

In fact, "the problem-ridden present" may be a euphemism for "capitalism returns to normal" after the glorious post-Second World War decades during which near-full employment, trade union organizations, social conflict and fear of the Soviet Union led to relatively fair deals in labour markets and relations, and to highly redistributive fiscal regimes. It is worth remembering that during the 1950s, under President Eisenhower, the United States had an average tax on profits of around 60 per cent and a top marginal rate on personal income of around 92 per cent – as well as the highest growth and investment rates in its entire history.

All this concerns the long-term patterns.[4] Conversely, in the shorter term other trends – to repeat, relatively independent of major technological changes – have deeply affected income distribution, labour relations and working conditions. We briefly consider a few of them below.

[4] In the following paragraphs we refer primarily to statistical evidence from the United States, which is the most complete. However, the qualitative patterns are similar in most OECD countries.

Figure 1. The relationship between productivity and wages

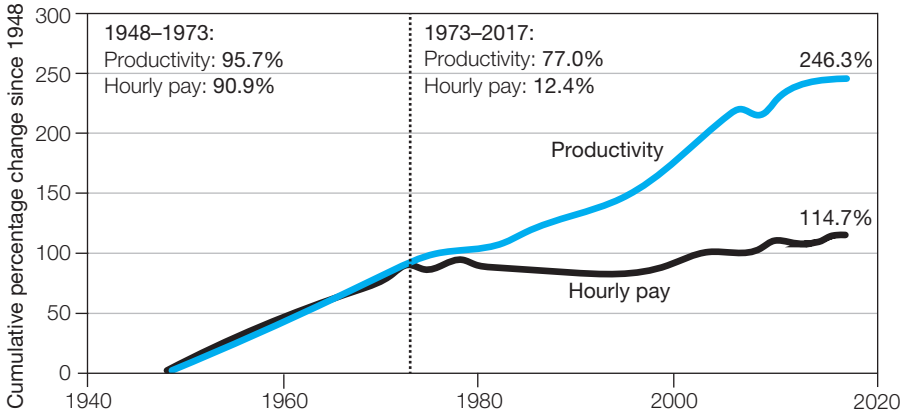


Source: Allen (2017, p. 323).

Trend 1: Globalization and the emergence of China as the world's factory

After 40 years of promotion of free trade, the liberalization of capital movements clearly turned out to be one of the main drivers of instability and a precursor of financial and economic crises (Stiglitz, 2002). In real economic terms, global value chain distribution has resulted in an international division of labour that works in favour of certain high-skilled workers and capital owners in both developed countries (where the middle class loses out) and developing countries (where factory workers are massively exploited), exacerbating inequality and social divides. A large share of the value of international products and services is still created in establishments located in developed countries, while the low value added phase of the production process has tended to be offshored (Timmer et al., 2014; UNCTAD, 2018). However, the most striking phenomenon has been the emergence of China as the world's factory. In a few decades of spectacular growth, China became the world's biggest manufacturer, catching up at all points along the value chain and in most production activities, from low to high technology. This development, however, was also accompanied by a massive change in the international distribution of working conditions, as we discuss in the next section.

Figure 2. The wage–productivity gap in the United States, 1948–2017



Source: Bivens and Mishel (2015, p. 4).

Trend 2: Stagnant wages and divergence between productivity growth and wage growth

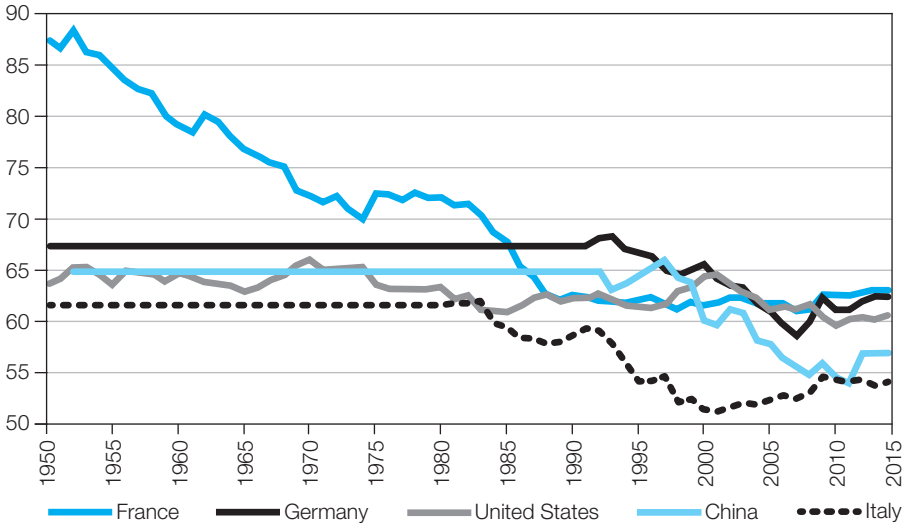
While the golden age of capitalism was characterized by balanced wage/productivity growth and a constant wage share of GDP, since the 1980s the wage–productivity nexus has weakened, with a declining pass-through from the latter to the former (figure 2).[5] The decoupling of the two elements is highlighted by two concurrent factors: a declining labour share of GDP (figure 3) and a widening gap between median and mean wage income (Schwellnus, Kappeler and Pionnier, 2017; Hutchinson and Persyn, 2012; Karabarbounis and Neiman, 2014).

Trend 3: A surge in corporate profits and top-level incomes

Profits and top incomes are the only components of GDP to have surged in recent decades, most likely owing to weaker labour bargaining power and the deterioration of labour market institutions. Moreover, as figure 4 shows, corporate profits proved to be extremely resilient during the Great Recession, declining temporarily before immediately rebounding as a result of massive growth (Dabla-Norris et al., 2015). Even the International Monetary Fund points a finger at the transformation of labour market institutions as the source of both functional and personal income inequalities (Jaumotte and Buitron, 2015). Extremely relevant here are declining unionization rates, as unions have always played a major role in promoting relatively egalitarian income distribution both at the aggregate level (figure 5) and at the level of the firm (figure 6).

[5] The apparent scaling difference between figure 1 (long-term trends) and figure 2 (post-Second World War trends) can be attributed to the fact that the former is based on wages per worker and the latter on wages per hour.

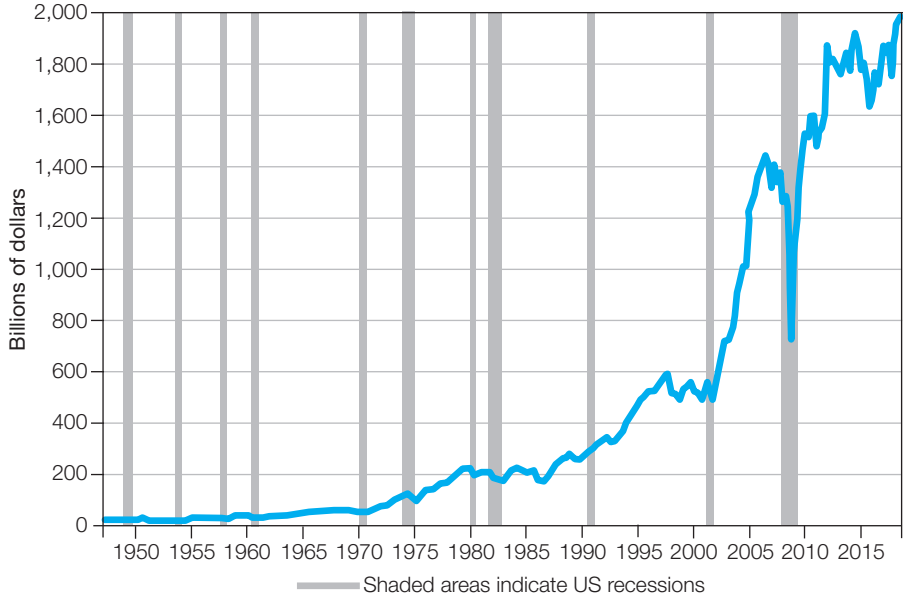
Figure 3. Declining labour share in China, France, Germany, Italy and the United States, 1950–2015 (percentages)



Note: Labour compensation measured at current national prices.

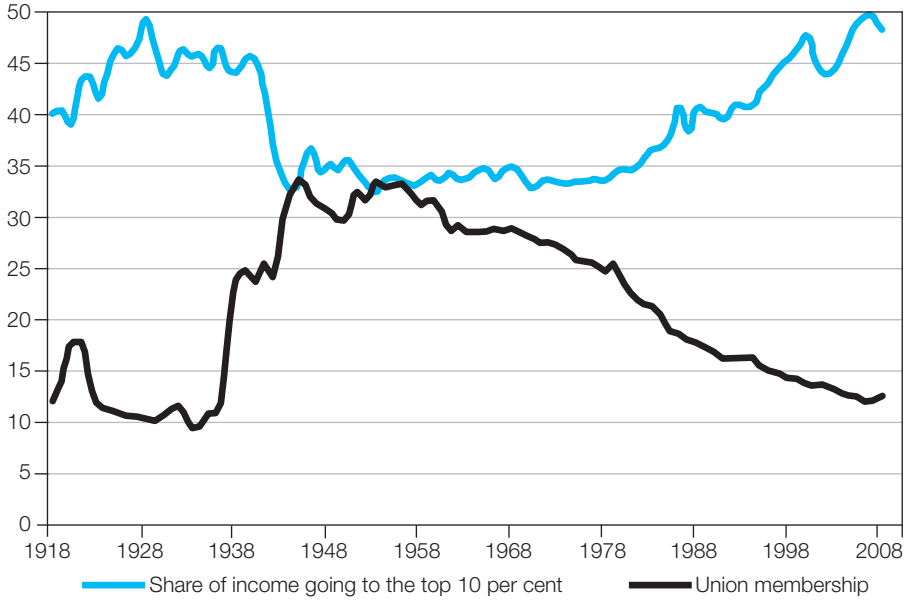
Source: Federal Reserve Economic Data.

Figure 4. Surge in corporate profits in the United States, 1950–2015



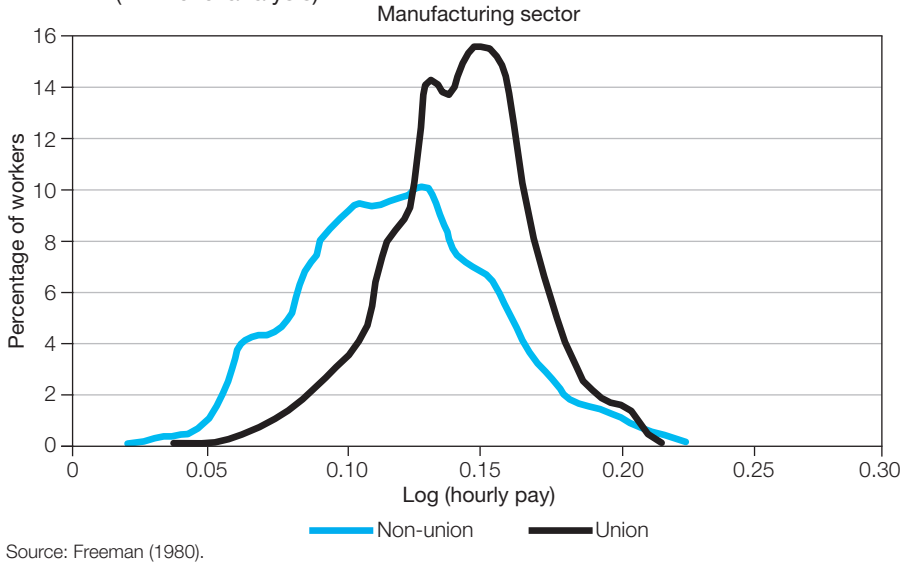
Source: Federal Reserve Economic Data.

Figure 5. Falling unionization and widening income inequality in the United States, 1918–2008 (percentages)



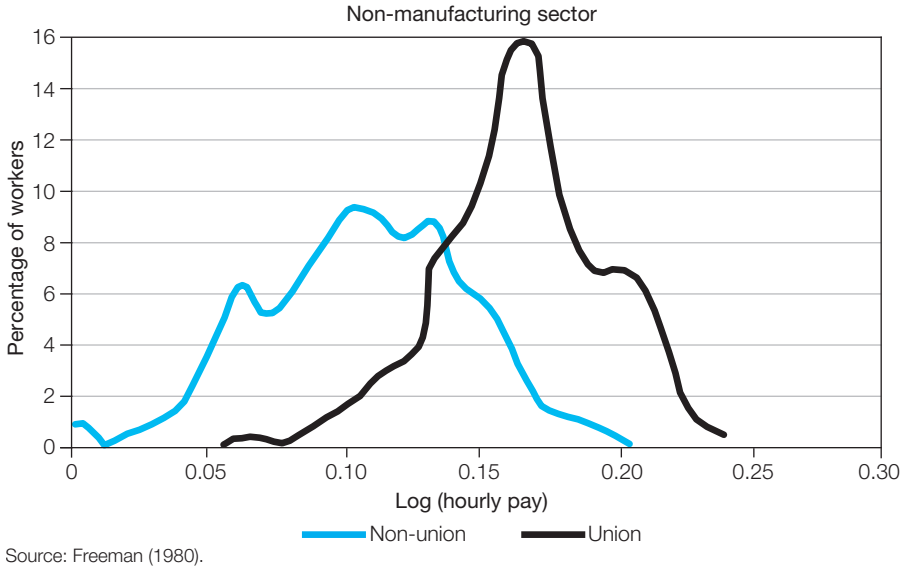
Source: Gordon and Eisenbrey (2012).

Figure 6. The more egalitarian wage distribution under unionization (firm-level analysis)



Source: Freeman (1980).

Figure 6. The more egalitarian wage distribution under unionization (firm-level analysis) *(concl.)*



Source: Freeman (1980).

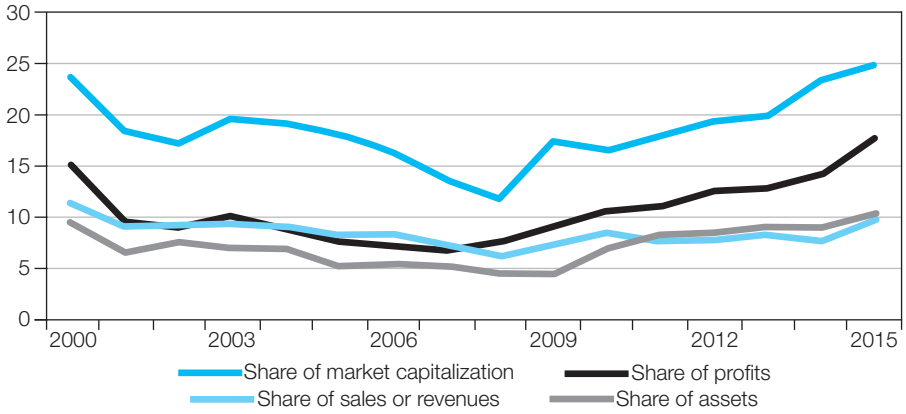
Trend 4: The trend towards winner-takes-all dynamics, especially in the knowledge economy

Concentration and "monopoly capitalism" are well-known traits of capitalist development (Hilferding, 1910; Lenin, 1917), but what we call the "rentification of capitalism" has seen new traits emerging in relation to the role of big tech companies.[6]

First, these companies are experiencing unprecedented market capitalization completely unrelated to the value and price of the products they sell. Their extremely high capitalization rests not on market fundamentals, but on the speculative bets of financial markets on massive ownership of individual data that can be used to profile both consumers and individual citizens (as seen in the 2018 Cambridge Analytica scandal). The valuation of these tech companies is therefore based not on the products they manufacture, but on the knowledge they possess and the power they therefore have. This is highlighted in figure 7, which shows the shares of the big tech companies among the top 100 transnational corporations, in terms of market capitalization, profits, physical assets and revenues. Strikingly, while the market concentration in terms of sales remained unaltered between 2000 and 2015, the share

[6] In the late twentieth century, it was commonly held that information and communication technologies would render industrial organization less concentrated and more distributed. We take issue with that view, analysing concentration patterns in manufacturing until the new millennium, as identified in Dosi et al. (2008). However, the big jump in overall concentration came with the explosive growth of information-intensive firms such as Google and Facebook (see Andrews, Criscuolo and Gal, 2016).

Figure 7. Big tech companies relative to the top 100 non-financial corporations, 2000–15 (percentages)



Source: UNCTAD (2018, p. 80).

of market capitalization and profits increased significantly. Looking back to before the dot-com bubble burst, figure 8 shows that the former almost doubled between 1996 and 2015, while the share of employment remained roughly constant during the same period (around 25 per cent of total employment in the top non-financial firms).

In fact, to appreciate the uncoupling between real market and financial market dynamics, suffice it to compare the 2018 *Fortune 500* list[7] ranking firms in terms of their revenues with the list ranking them in terms of profitability.[8] Walmart ranks first in the former but only 20th in the latter. Conversely, Facebook ranks 76th on the first list and 12th on the second.

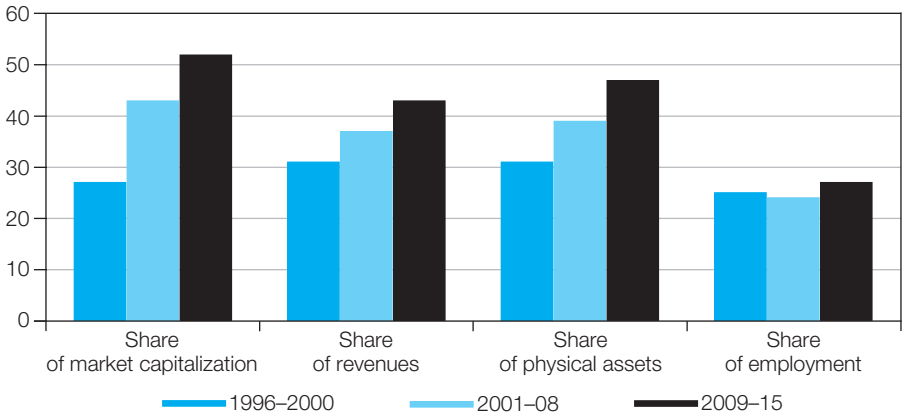
Another aspect of the rentification of the economy is the financialization of non-financial firms, which use the profits they generate from doing business to fund financial investment in the companies themselves or to increase shareholder wealth (Lazonick and Mazzucato, 2013; Lazonick, 2014). As a result, the Big Four – Amazon, Google, Apple and Facebook – control more financial assets than many of the top investment banks. Many firms increasingly use their profits to buy back their own shares, instead of ploughing them back into physical and research investments, for the sole purpose of increasing the value of their stockholders' assets.

It should be noted that the concept of rentification used here is much more expansive than the concept of financialization, which it encompasses. The latter properly refers to the changing balance between real and financial investments. The former concerns the very mechanisms by which social product is generated and appropriated. Rents have always existed – as per the law of rent expounded by Ricardo (1821) – but have historically been a "parasitic tax"

[7] See http://fortune.com/fortune500/.

[8] See http://fortune.com/fortune500/list/filtered?sortBy=profits&first500.

Figure 8. Big tech companies relative to the top 100 non-financial corporations, 1996–2015 (percentages)



Source: UNCTAD (2018, p. 80).

on the process of transformation of inputs into outputs: in Ricardo's example, capitalists hire workers to plant and harvest corn, but in order to do that they have to pay some share of the value added to the "rentiers".

A first form of further rentification is the exercise of monopoly power over what is produced. For example, the prices charged by big pharmaceutical companies have nothing to do with the cost of production but are simply "the maximum the buyer is willing to pay". However, when capitalism becomes rentified the processes of value creation and value extraction become increasingly de-linked. The latter no longer relies on transformation, but instead on three other processes, namely, exclusion, the "marketization" of previously non-economic activities, and their appropriation.

Exclusion works by creating fictitious value for physical and immaterial assets stemming from limitations to access them. This is clearly the case of real estate rents. After all, an apartment in Manhattan and a house in the Bronx satisfy the same basic need; however, thanks to exclusion, their exchange values are dramatically (and increasingly) different. Exclusion concerns more generally all "positional" goods and services (Hirsch, 1976), where the "value" comes from the very exclusion of other potential users (e.g. visiting the Galapagos Islands alone).

Another major driver of rentification is the marketization of activities that were previously (fully or partly) outside the market domain: health and education are two major cases in point. Appropriation, or rather, digital appropriation, consists in the extraction and collection of individual immaterial assets (mainly data) with the aim of monetizing them (discussed in the next section). Exclusion, marketization and appropriation today appear to make ever-higher claims on the total social product in the form of huge rents.

Trend 5: Polarization and casualization of work

The service economy, today home to the largest segment of the working population in advanced economies, is undergoing rapid transformation in a process increasingly characterized by non-standard and flexible forms of labour relations and contractual regulation. This is linked to deteriorating patterns of working conditions, to neo-Taylorism (both physical and digital) and to a profound absence of legal protection of gig workers' rights.

All the foregoing factors may well threaten societal, political and economic sustainability also because they affect the universality of the welfare system in domains such as education, health and pensions, deepening inequality in opportunities and actual living standards. They may interact with and amplify the effects of technological change. But what type of technological change?

The emergence of a new techno-economic paradigm?

The modern industrial sector is clearly characterized by the massive introduction of robotic devices able to take the place of humans for repetitive and routine activities. However, even in the service sector – which, we repeat, employs the lion's share of labour in advanced economies – artificial intelligence and software developments are becoming increasingly relevant. Robotization and artificial intelligence therefore represent a direct threat for white-collar as well as blue-collar workers. That IBM's Deep Blue computer was able to defeat world chess champion Gary Kasparov came as no great surprise; in chess, human heuristics can be replaced by a complete search of highly dimensional, but finite, combinatorics of moves. However, in 2004, IBM software developers tackled a huge new challenge: to program Watson, a computer able to beat the human champion in Jeopardy. Unlike chess, Jeopardy is an open-ended game that requires advanced learning, linguistic, semantic and association skills – cognitive capacities that do not at all figure among a computer's standard "skill set". In 2011, Watson beat two world champions in Jeopardy, demonstrating that machines are able not only to compute, but also to understand, learn and react to changing information and environments – and may therefore indeed be becoming "intelligent". Robots are now able to compose music, write newspaper articles, grade high school tests, paint and play the piano. If their "intelligence" is borne out, even higher cognitive abilities may be potentially threatened by technology.[9]

Is this good or bad news? The explicit purpose of many Silicon Valley and Boston area start-ups is to create and develop technologies able to replace human labour entirely. Momentum Machine, for example, was founded with the aim of completely automatizing the production of gourmet hamburgers. The founders expressly state that their device is not intended to increase labour efficiency but rather to get rid of human labour altogether (Ford, 2015).

[9] Artificial intelligence has also met with plenty of failures. The use of a massive open online course (MOOC), for example, to spur online learning revealed that it failed utterly to promote education for low-income students (Ford, 2015).

Conversely, sectors such as medicine and health care are still missing robots and machine-learning algorithms whose widespread application could complement human activity rather than replace it. There is ample potential to expand the use of robots and artificial intelligence far beyond the sectors in which it has become routine – such as fast-food production and delivery – to those, like medicine and health care, in which costs are rising disproportionately, threatening the right to health care of a soaring fraction of the population both in countries that have universal coverage (like most European countries) and in those that do not (like the United States).

Does all this add up to a "Fourth Industrial Revolution"? Or does it form part of the incremental deepening and convergence of pre-existing technological paradigms? These questions are crucial, as they lie at the heart of the analysis of continuities and discontinuities in the knowledge base, of the institutions and firms generating and supporting them, and of the national location of leading players. Here we need to distinguish between the so-called Industry 4.0 (I4.0) managerial and policy strategies, on the one hand, and the evidence pointing to the arrival of a breakthrough technological revolution, on the other. With respect to the latter, a series of industry studies on the manufacturing sector that looked at the technological and organizational implementation of I4.0 found hardly any signs of emerging revolutionary change inside I4.0 factories (see Cirillo et al., 2018). In general, the organizational changes accompanying the adoption of I4.0 technologies tended to fall in line with the lean production paradigm (Womack, Daniel and Roos, 2007). In many respects, the I4.0 strategy, which fosters "lean" production systems, hardly represents a paradigm shift. Rather, the drive towards customization, inventory reduction, bottleneck elimination, error tracking and working-time intensification and saturation overlaps remarkably with the first wave of lean production that began in the late 1970s.

A stronger hint at paradigmatic change lies in the pervasive collection and use of data to achieve control over the social/reproduction spheres of individuals. In 2014, the State Council of China released a document launching a new pilot project, the Social Credit System. The project, whose name is redolent of some form of welfare state intervention, actually represents the first government-endorsed programme wherein "big data meets Big Brother", and is intended to rank individual citizens by their degree of social conformity (see Botsman, 2017). By engaging in the massive collection of individual data and mapping individuals' entire social spheres, the programme will determine whether people get the jobs they want, what schools they can enrol their children in and whether they are free to travel abroad contingent on their individual degree of trustworthiness. For obvious reasons, the ranking algorithm is closed source and proprietary, although various factors are known to be in play: being a good taxpayer and a good borrower (in the sense of meeting deadlines), together with personal and interpersonal characteristics, preferences and behaviour. The system provides both rewards (such as free loans) and punishments (such as restricted mobility) and is managed by a credit

service company related to the Alibaba Group. Clearly, the possibility, leveraged by big-data collection and analytics, of regulating an individual's entire social sphere represents the most extreme form of digital control.

On the other side of the world, such control opportunities are currently being massively exploited by high-tech companies. Recently, Zuboff (2015) introduced the concept of a new system of capital organization, called "surveillance capitalism". The Chinese "Big Brother" becomes the US "Big Other", placing data generation/extraction, data analysis and data selling at the heart of this new accumulation system. It involves several steps.

The first step is largely a labour-intensive activity ranging from involuntary consumer data generation whenever transactions occur on individual consumption patterns, to piece-work activity involving click farms or generic crowdwork platforms and micro-work activities, such as Amazon's Mechanical Turk (Casilli, 2017; Huws, 2014). Not only humans, but also machines, and particularly robots, when integrated by means of sensors, become data generators. Such patterns are particularly relevant for the industrial sector. This activity basically consists of extraction, given that in most cases data are simply appropriated, even by means of intrusive and brute-force practices, such as data storage or illegal breach of individual privacy. In this sense, the current phase of capital accumulation is more closely akin to a rentier economy than to a productive capitalist economy, wherein both producers and consumers/workers enjoy the benefits of the value-creation process.

The second step centres on the massive profiling of consumers/users by means of artificial intelligence, a computationally intensive process relying mainly on supervised (e.g. artificial neural networks) and unsupervised (e.g. text mining and natural language processing) machine-learning techniques.

The final step is data selling: the profiles generated are bundled and sold to other companies that then attempt to manipulate individual behaviour through targeted advertising. All this takes the tendency to create new consumer needs to a higher, unprecedented level, delivering advertising and content directly to those consumers who are already known to exhibit the highest absorptive potential.

The Big Other, it turns out, is basically as coercive as the Big Brother. In fact, its power is so pervasive that users will choose a given set of actions not out of a fear of control involving conscious self-control and a sense of conformity, but because they perceive that choice as their own personal idea regarding, for instance, the best restaurant, travel destination, accommodation or political preference. This occurs because the algorithm influences and predefines the repertoire not only of admissible actions, but also of conceivable ones.

Technology, productivity and growth

Given the foregoing historical patterns, let us take a closer look at the general relationship between technology, productivity and growth. In a first approximation, technological progress is the core driver of economic growth. Since the Industrial Revolution, which saw the introduction of mechanization and

specialization in industrial production, machines have helped human activity improve the quantity (and also the quality) of production (Freeman, 2019; Dosi, 1984). In turn, technological innovation has been translated into productivity, and the latter into economic growth. But this is just a first, and indeed quite rough, approximation. To see this, consider the identity:

$$g_y = g_\pi + g_n$$

From an accounting point of view, this is just an identity that tells us that the growth rate *(g)* of aggregate income *y* is given by the sum of the growth rate of productivity π and the growth rate of the working population *n*. In terms of the theory of growth, however, it is much more complicated. In order to say that it is the growth of productivity and demography that directly drives GDP growth, it must of necessity be assumed that: (a) the initial conditions are equilibrium ones; (b) the rate of growth of the working population corresponds to the rate of growth of the labour supply – i.e. the system is in equilibrium at least in the long run, with no involuntary unemployment and no endogenous changes in the participation rates; and (c) productivity growth is exogenous, or, if endogenous, does not involve feedback between income growth rates and productivity growth (hence, no Smith-Young-Kaldor dynamic increasing returns). Here, however, we advocate a quite different story.

It is an evident stylized fact of modern economic systems that there are forces at work that hold them together and make them grow despite rapid and profound modifications of their industrial structures, social relations, production techniques and consumption patterns. We must better understand these forces in order to explain possible structural causes of instability and/or cyclicity in performance variables. It might be useful to start from a more explicit definition of "dynamic stability" and "homoeostasis". We probably live in the first social structure where technological, social and economic changes are fundamental features of how it functions. For the first time, what we call the "bicycle postulate" applies: in order to stay up, you have to keep pedalling (Dosi and Virgillito, 2017). It is the system's very growth and development that yields the conditions of its (imperfect) coordination. However, change and transformation are by nature "disequilibrating" forces. Thus, there must be other factors that maintain relatively ordered configurations of the system and allow broad consistency between the conditions of material reproduction (including income distribution, accumulation, available techniques, patterns of consumption) and the web of social relations. In a loose thermodynamic analogy, this is what some French authors call "regulation". The problem of long-term discontinuities or waves of innovation, which might result in changes to macroeconomic activity rates, pertains precisely to this level of analysis: are there structural features that produce crises in regulation set-ups?

We can distinguish three main domains in the overall socio-economic fabric, namely, the system of technologies, the economic machine, and the system of social relations and institutions. These three domains clearly interact with one another. Our analysis will therefore build on the following hypotheses:

- Despite powerful interactions, each of these three domains has rules of its own that shape and constrain every inducement and adjustment mechanism between them.
- There is a limited number of ways in which these three domains can be configured so as to be relatively well regulated and smoothly consistent.
- Unbalanced or crisis configurations do not necessarily embody the need to transition to another configuration.

In capitalist economies, where conflict over labour processes, income distribution and power are structural features, labour saving is bound to be one of the fundamental dimensions of most technological trajectories. Moreover, any labour saving upstream in the production of commodities that are also productive inputs represents an input saving, in value terms, downstream. Developed industrial systems are functionally characterized, in normal circumstances, by reproducibility and not scarcity, demand-pulled in terms of macroeconomic activity, and balance-of-payment constrained. Under these conditions, paramount importance must be attributed to the broad duality of technological change, which continuously saves labour, on the one hand, and creates new markets or expands existing ones, on the other, by changing the cost and price of each commodity and service. The balance between demand creation and labour displacement defines the endogenously generated rates of macroeconomic activity and labour force use. The dual economic features of technical progress are affected by the pattern of consistency (or the mismatch) between:

- the nature of the fundamental technological paradigms;
- the nature of the associated production and labour processes;
- the mechanisms of interaction between the major social groups; and
- baskets of consumption, which are a function of income level, income distribution and – depending on the latter – the ways in which societies organize the use of non-working time and the provision of services, among others.

Years after the Great Recession, European growth remains anaemic and concern is mounting that the crisis has permanently slowed productivity growth, thus reducing long-term growth prospects in a way that is reminiscent of hysteresis (see Dosi et al., 2018a). Concerning the United States, Syverson (2017) recently showed that between 1995 and 2015 productivity growth dropped by more than half, from 2.8 per cent (1995–2004) to 1.3 per cent (2005–15). A similar pattern emerged in 29 of the 30 countries analysed in the same study, with an average decline of 1.2 percentage points.

Are we really facing the end of innovative opportunities? Or are we instead witnessing the exhaustion of a growth regime characterized by a smooth match between product and process innovation, productivity gains, their distribution as wage increases, the sustained formation of aggregate demand and, ultimately, sustained GDP growth?

Certainly, at least since the Industrial Revolution, Landes' (1969) "unbound Prometheus" of technological innovation has driven mechanization

and specialization in production processes while generating a growing variety of products, leading to a secular increase in productivity and per capita GDP. That happened throughout the different waves of industrialization (or industrial revolutions) characterized by different techno-economic paradigms (Freeman and Perez, 1988), from the steam engine to the potential "Fourth Industrial Revolution". Some scholars nevertheless argue that this secular drive has been exhausted, both in terms of productivity growth and of the creation of new investment and consumption opportunities comparable to those associated with the revolutions in means of transport, urbanization, central heating, electrification, and so on (Gordon, 2012). Have those social needs been exhausted? Hardly.

The reasons for the productivity slowdown are most likely diverse and potentially attributable to many, possibly complementary causes. Some pertain to the supply side, including lags in the spread of the latest wave of new technological paradigms and the lack of organizational capabilities and skills needed to exploit them fully. After all, major new technologies – namely, those based on electricity – took roughly a century to reveal their full potential. Today, we find ourselves at the very start of the digitalization of the economy and of society – as information and communication technologies, automation and artificial intelligence converge – and have only just begun to explore the potential of bio- and nano-technologies and new materials. Other possible causes of the apparent productivity slowdown pertain to the demand side and the interaction between it and the rate and direction of innovation.

For sure, well before the Great Recession, the strikingly successful patterns of socio-economic growth observed during three glorious decades after the Second World War started unravelling as the smooth match between technological innovation, productivity growth, income distribution and aggregate demand increasingly broke down (see the broad trends discussed above). It should be recalled that, on the technological side, sustained growth rates were based on the rapid development of a few fundamental technologies, such as automobiles, electrical consumer durables, capital equipment used in mass production and Tayloristic production processes. On the institutional and labour sides, some form of inclusive social compromise guaranteed relatively equal income distribution, a rough indexation of wages on productivity growth and a political commitment to near full employment. In turn, the foregoing conditions of income distribution fostered sustained growth of consumption, a bullish view of investment and overall growth of aggregate demand.

In any case, it is crucial to note that our discussion so far and below is clearly distinct from a comparative examination of "techno-optimism" (e.g. Brynjolfsson and McAfee, 2014) and "techno-pessimism" (e.g. Gordon, 2012). Both views are fundamentally predicated on the intrinsic nature of the new technologies and the existence of a direct link between trends in technology, productivity and growth. On the contrary, especially at junctures like today's, the ultimate outcome will result from interaction between the major social players, such as firms, organized labour, civil society and States. One point

that we want clearly to deny is that the richness of such dynamics could be squeezed into the estimate of the changing parameters of an otherwise invariant production function. By the same token, we find it hard to take seriously any interpretation of unemployment rates and remuneration in terms of work/leisure trade-offs[10] and the attribution of the ensuing partial derivatives of aggregate productivities to specific skills. We may be headed for either "work for all" or "mass unemployment" (Freeman and Soete, 1994), but which one we end up with depends entirely on us.

Technology and jobs

Technology affects labour demand through a variety of channels and has been one of the thorniest issues at least since David Ricardo (1821) added a chapter "On Machinery" to his seminal book. As we know, it is often referred to as the problem of compensation mechanisms (Vivarelli, 2014). Technological change, demand and employment are linked in at least four ways: (a) via productivity growth lowering prices and leading to higher demand (under positive price elasticities); (b) through productivity growth raising real wages and leading to higher demand; (c) conversely, through productivity growth causing labour displacement and leading to higher unemployment and lower demand; and (d) through product innovations, which have always created new sources of demand and new forms of employment. The question thus arises: what has happened and is happening to the relative importance of product- vs process-related technological advances. Has it changed? In which direction?

Of course, there is a sectoral dimension to these dynamics. Considered from a bird's-eye view, the pattern of economic growth has historically been associated with labour force movement from agriculture to manufacturing and, ultimately, to the service sector. To what extent the process of structural change is accompanied by job creation or destruction boils down to whether output growth (demand) is higher or lower than productivity growth. Demand growth and productivity growth are linked via the price elasticity: productivity dynamics, in so far as they reduce prices, spur demand in sectors experiencing high productivity growth (see Kuznets, 1955; Clark, 1957; Baumol, 1967; Pasinetti, 1981).

The other driver is to be found in the income elasticities of demand. Employment-absorbing sectors (towards which the labour force tends to move) have been generally characterized by high income elasticity of demand, especially in the initial phase of development (Freeman, Clark and Soete, 1982). While high income and price elasticities of demand may compensate, or more than compensate, for the labour-saving effect of process innovation, under conditions of increasing returns demand growth influences productivity dynamics

[10] Conversely, it is hardly plausible that the bifurcation will be driven by the choice of a "representative worker/consumer" determined by the relative price of leisure, as extreme versions of equilibrium theory would suggest. The working poor certainly do not work more than before because the cost of watching Netflix (which is basically free) has increased.

(the Verdoorn-Kaldor law). Such virtuous circles apply primarily to manufacturing and certainly were at work during the post-Second World War boom. Are they still at work now?

In the past, the transition from agriculture to industry meant a shift from lower to higher productivity sectors that was simultaneously characterized by high income elasticities of demand; similarly, industry itself shifted from traditional manufacturing to consumer durables (such as cars, white goods and television sets). Conversely, the manufacturing activities associated with today's new technological paradigms continue to be in high productivity subsectors (e.g. ICTs, robotics, biotechnology) but (still) account for a relatively low share of aggregate demand and employment.

Altogether, the bulk of the current transition appears to be from manufacturing to services and to be characterized *prima facie* by what appears to be lower productivity. Measurement is clearly an issue here, as it is hardly possible to apply the same yardstick to value added in health care and in car manufacturing. In relatively wealthy, ageing societies, however, the share of health services, elderly care and other welfare services is growing and bound to grow further. Indeed, the health-care sector may spawn a new wave of innovation and technological development. And yet, it is hard to imagine that it will result in increasing return processes similar to manufacturing, almost mechanically linking demand growth and productivity growth, however they are measured. This poses a formidable policy challenge, which we further discuss in our concluding section. Of course, the processes of automation and robotization in industry and, increasingly, the service sector are having and will continue to have a profound effect on labour productivity.[11] In fact, this is going to be a major topic of research in the years to come, together with the lag structure by which the related innovations are likely to spread throughout the economy.

Technological innovation obviously has a strong impact on jobs, in terms of both quality and quantity. Many scholars have started studying how the introduction of new technologies has affected the set of worker skills that firms demand (for a literature review, see Autor, 2015). According to Autor, along the entire skills range, automation and computerization turn out to be substitutes for more routinized activities and complement high-skilled non-routinized jobs, with more limited effects on low-skilled, non-routinized jobs (ibid.). The outcome of these dynamics suggests a pattern in which medium-skilled jobs will gradually disappear, while the demand for both low-skilled and high-skilled jobs will remain stable or even rise. The consequence of the suggested simultaneous relative growth in demand for highly skilled/high-wage workers and low-skilled/low-wage workers is a process of both wage and skills polarization.[12]

[11] This is not the place to discuss why we focus on labour productivity and not on what is known as total factor productivity, as many economists do. Suffice it to say that, in a world where capital inputs and labour are complementary and where the former are produced under conditions of non-decreasing returns, total factor productivity measures are likely to be meaningless or even misleading.

[12] For a cross-country comparison of the dynamics of routinized jobs, see Marcolin, Miroudot and Squicciarini (2019).

In turn, the change in skill composition may also affect the ability of Western economies to regain their pre-crisis employment levels (see Jaimovich and Siu, 2012). In this regard, the extent to which routinized (manual and cognitive) skills have been and will be automated may help explain the phenomenon of jobless recoveries. Indeed, the drop in demand for routinized skills has been particularly steep since the 1991 recession. Before that, routine occupations would be hit but were able to recover effectively and, even in recessions, demand for non-routine occupations generally tended to rise. Post-1991, however, the skills associated with routine occupations were not only severely displaced in the recessionary phase, they have never managed to recover. After the 1991 and 2001 recessions in particular, the return to pre-crisis employment rates appeared to be mostly driven by mounting demand for non-routine occupations. After the Great Recession, more worryingly, routine occupations were hit particularly hard and, for the first time since the 1970s, demand for non-routine occupations also declined.

The concept of routinization discussed above often comes with a simplistic view of the relationship between automation and tasks. In fact, the fundamental link between technologies and operational tasks lies in organizational routines, as we discuss in the next section. Moreover, many studies conclude that the sources of inequality have little to do with any purported skill/routine-biased technical change, but are instead to be found in the dismantling of labour market institutions (for elaboration, see Freeman, 2015; Dosi et al., 2018b).

Structural change also plays a paramount role across sectors. Jaimovich and Siu (2012) report that job losses in manufacturing account for 38 per cent of job polarization since the 1990s. In this respect, Groshen and Potter (2003) investigated whether the process of structural change is a determinant of jobless recovery, focusing on the 2001 crisis in the United States.[13] They suggest that this is indeed the case, highlighting the predominance of permanent over temporary job losses and the shift of jobs across industries. In fact, they argue that the very low rehire rates are evidence that fired workers generally found jobs in other firms and sectors. Distinguishing between cyclical and countercyclical flows, and between structural gains and losses, they suggest that, while downturns in the 1970s and 1980s were characterized by a mix of cyclical and structural adjustments (50 per cent, respectively), the share of structural adjustments increased to 57 per cent and 79 per cent in 1990–91 and 2001, respectively. Needless to say, such changes in the economic structure of the United States (and more generally in Western economies) are closely related to the aforementioned rise of China as the world's factory.

Further evidence of the connection between job polarization and structural change is provided by Bárány and Siegel (2018), who propose a model in which they link the tripartite classification of skills (manual, routine and ab-

[13] In some countries, like the United States, the unemployment rate has apparently fallen, but this is mainly due to a shrinking active population and growth in involuntary part-time jobs (Bell and Blanchflower, 2018).

stract) proposed by Autor, Levy and Murnane (2003) with low-skilled services, manufacturing and high-skilled services, respectively. They argue that there is a clear overlap between the routine–skills and industry–occupation categories. In particular, the dynamics of the share of manufacturing and of routinized skills appear to be quite similar. Furthermore, an in-depth examination of the industry–occupation categories prompts them to suggest that the decline in employment in routine activities is deep and persistent only in the manufacturing sector. Conversely, employment in routine activities in low-skilled and high-skilled services is increasingly rising or remaining stable, respectively.

Of course, the overall quantity of jobs should be a major analytical and policy concern. Given the massive use of automated processes that can be substituted for human labour, the threat of technological unemployment is an issue that concerns micro-, sectoral and macro-dynamics. The relationship between innovation and employment at the micro- and sectoral levels is discussed in Calvino and Virgillito (2018) and, focusing on China, in Dosi and Yu (2018). The evidence broadly suggests a positive relationship, primarily with respect to product innovation and in inter-firm comparisons. However, it may well be that more innovative firms also grow more in terms of employment but at the expense of other firms, such that the overall effect may be negative. In order to properly address that issue, consideration should be given to the sectoral and intersectoral dynamics of innovation and employment – a general disequilibrium perspective that is still largely absent.

An alternative angle of analysis entails the exploitation of geographic differences in some proxies for innovation propensities and in the composition of employment, building a sort of geographical job multiplier (Moretti, 2012). The conjecture is that highly innovative sectors have a higher multiplier, as high-tech jobs in the tradable sector appear to be attached to many more jobs in non-traded sectors. Highly innovative sectors are identified as those where high productivity increases occur, and such productivity gains, transferred into high incomes, trickle down to demand for non-tradable goods.

This account of the process is open to many criticisms, however. First, information-intensive technologies are likely to generate far fewer jobs than traditional manufacturing ones (the number of people employed by a leading new-tech firm like Google is an order of magnitude lower than a traditional/declining firm like General Motors). At a time of much more unequal income distribution like the present, the ratio of productive to non-tradable workers is likely to be lower in Silicon Valley than in Detroit, albeit in a purely statistical picture of more unequal techno-economic dynamics. Second, we have to move beyond pure compositional exercises and pay much closer attention not only to the number of jobs created, but also to their quality and to the salaries they pay. Otherwise, we may easily end up with a servant-heavy society in which rich people employ dozens of individuals to satisfy their personal needs. Thirdly, highly unequal societies are likely to be associated with collective negative externalities. So, for example, high-income jobs tend to foment a surge in living costs, particularly exploding home prices.

Combined with wage stagnation and more and more lay-offs, these patterns both heighten the rentification of the economy discussed earlier and further worsen quality of life for the majority of the population. One example of this can be seen in the problem of homelessness in the mythical Silicon Valley.[14] Although there is a glaring lack of accurate analyses, a big chunk of the rise in homelessness can be put down to the arrival of high-tech firms, which have produced a tremendous increase in the cost of housing (a one-bedroom apartment rents for US$3,000 per month, far beyond the means of an engineer on an annual gross income of around US$80,000). All this should set alarm bells ringing as to the new patterns of job creation resulting from "capitalism 4.0".

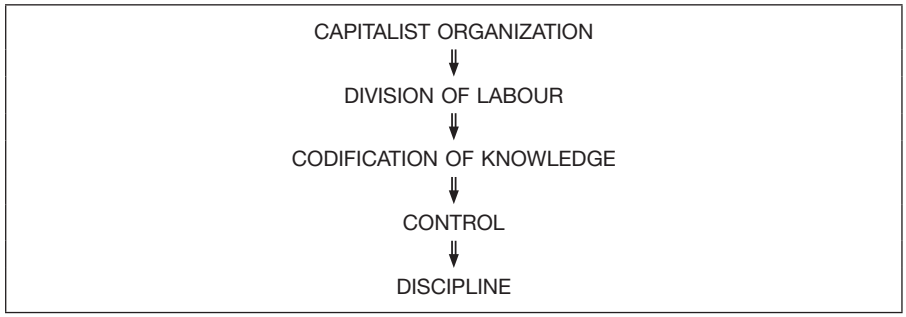
By the same token, the time has come to start questioning the extent to which big tech firms are genuine creators of new knowledge and what can justify the enormous inequality that they are producing by preying on the information distributed across society. In many cases, in fact, the "knowledge" they produce is a recombination of existing pieces of information put together for the purpose of creating purportedly new needs to be satisfied, or better, to satisfy very old needs with purported new technology. Social networks, for instance, serve mainly to chat, gossip and meet people, but they transfer these very basic and old human needs into a virtual, unknown reality. Together, these systems extract more value than they create by monitoring people, and tracking and selling consumer profiles.

Division of labour, knowledge and power

Capitalism, by its very nature, has always involved the power to organize labour. Historically, ever since the First Industrial Revolution, which entailed a combination of new technological paradigms and organizational innovations, this has been achieved by rationalizing the production process. In the masterful words of Adam Smith (1776), the division of labour into organized units dramatically increased productivity, by transferring knowledge from disorganized artisans and part-time farmers to hierarchical forms of production. In so doing, the initial phase of capitalist development entailed a first massive process of labour deskilling. Successive waves followed, from the "Taylorist movement" to the present. Braverman (1974) analyses those dynamics in contemporary capitalism, detailing the micro-organization of the so-called labour process: the working class is analysed from the point of view of its relationship with the machine, the shop floor, management and the related control. Under capitalism, the management structure is such that the knowledge embodied in workers should be transferred to machines. In this respect, the process of technological change has entailed a secular trend towards deskilling whereby the machine makes once tacit knowledge codifiable (Nuvolari, 2002).

[14] See https://en.wikipedia.org/wiki/Homelessness_in_the_San_Francisco_Bay_Area [accessed 21 August 2019].

Figure 9. The relationship between capitalist organization, knowledge and power



To understand the relationship between humans and machines, it is crucial to comprehend the evolutionary process driving technological change. Technology can be thought of as a recipe with "ingredients", associated "instructions" and "dos and don'ts". A recipe always embodies a degree of codified knowledge but its execution also requires non-codified and tacit know-how (unwritten procedures). In turn, the procedures are typically collective, implying mechanisms of coordination among members of the organization, whose execution of the recipe entails an ensemble of organizational routines. These therefore constitute a link between technology and organization, typically nested in hierarchical structures and power relations (Dosi and Marengo, 2015). Figure 9 illustrates this point. Given the tacit nature of the knowledge embodied in the execution of complex tasks, a "natural trajectory" in technical progress involves the progressive mechanization/automation of production processes and a drive to make routines simple, repetitive and codified. Control of production rhythms, correct execution of tasks, movements along the sequences of production, and workforce discipline have been and are the necessary conditions for the codification of knowledge.

While these patterns have existed since the emergence of capitalist societies – they are in fact a hallmark thereof – they now appear to be accelerating. More or less intelligent automation is fostering the very disappearance of quite a few of the foregoing tasks and related jobs, at least as they are performed by humans. It is hard to predict whether those losses will be offset by a comparable number of intelligent jobs, but the signs are hardly encouraging: even a more optimistic analyst like Moretti (2012) sees a large multiplier for gardeners, babysitters, hairdressers – we would add janitors – and, in the United States, prison guards and police officers.

Another major feature of today's technological transformations representing discontinuities vis-à-vis older patterns is the "dematerialization" of some sources of aggregate income. This is closely tied to a significant part of social activities being grounded in technologies that are, more than ever, akin to "information", especially in terms of output, but also input, as discussed above, yielding a form of privately appropriated information. Platforms characterized

by a combination of near-zero marginal access and reproduction costs, strong economies of scale and network effects are a good case in point (David, 1985). In order to take proper measure of its significance, let us briefly consider the specific features of information as an economic good (see Dosi and Nelson, 2010). First, information is non-rivalrous in use. Use by one economic agent in no way, in and of itself, limits the ability of other economic agents to use the same information. Second, the initial information involves high upfront generation costs compared to the lower costs of its repeated utilization. In fact, there is something genuinely special about information in general, and technical knowledge in particular, in that they share a sort of notional scale-free property: a fully developed idea does not, a priori, imply an intrinsic restriction on the scale of its implementation. We are reluctant to put it this way, but were there a production function with information as the only input, it would display an output equal to zero for information below one unit and a vertical line for information equal to one. Today's platforms are drawing closer to this archetype. Third, the use of information consequently has a fundamental property of increasing returns.[15] Implicit in the use of standard economic goods such as shoes and machine tools is that they are worn out by that use. The same does not apply to information. On the contrary, persistent use implies at the very least the information's non-depreciation.

In the combination of the foregoing dynamics in the division of knowledge, power and control, and the centralization and appropriation of information, the former are leading to a concentration of hierarchical power, even if this is often masked by a reduction in hierarchical layers. That reduction should be seen, on the contrary, as a tendency towards a more polarized social fabric of "one king and his subjects". Added to the contemporary use of platforms exploiting the properties of the economics of information, the inherent characteristics of the centralization and appropriation of information entail general non-convexities, a Matthew effect[16] and self-reinforcing processes implying multiple equilibria and trajectories. The two dynamics may be explosive: the unrestrained blending of tighter hierarchies with more information-driven centralization may make it easier to act exploitatively and lead to massive polarization in the distribution of power, knowledge and incomes. Taking the example of Uber, the main cost is setting up and marketing the platform. Once it is up and running, however, the costs of maintenance and expansion (marginal costs) are close to zero, while the service is delivered by exploiting the service providers (the drivers and their cars). This is not to say that all current

[15] All this entails a strong drive to monopolization, making the possibility of "contestability" even more remote (see Baumol, 1986, pp. 40–54). Indeed, increasing returns and path dependency stand against any representation of industrial organization that is so "fluid" that even nominal variables (prices) are as sticky as real stock variables (e.g. fixed investments), a necessary condition for "contestability".

[16] From the Parable of Talents, found in the gospel of Matthew: "For to all those who have, more will be given, and they will have an abundance; but from those who have nothing, even what they have will be taken away." (chapter 25, verses 14–30).

candidates to becoming information monopolists will survive. They are in fact, by definition, "unicorns"[17] and likely to fail, but until they do, they will radically change the industries in which they operate (Kenney and Zysman, 2016).

The gig economy is an even more extreme archetype.[18] The algorithms governing labour are not human beings against whom workers can strike. There is little hierarchy or, at least, no one between the worker and the algorithm. And the individual worker, along with many thousands of others, ends up in a pre-industrial condition, similar to the "putting-out" system that existed before industrial factories. Then, at least, English peasants doing part-time, flexible sewing work were able to cheat, steal some of the fabric and control their pace of work.

The case of the bicycle food delivery workers populating the streets of every metropolis today is another telling example. These workers use a relatively old, labour-intensive means of production (a bicycle) to provide a service that satisfies an even older, basic need (to eat) and they are controlled by extremely sophisticated software that acts as their boss, tracking and monitoring them, and sending productivity evaluation messages (time to accept orders, time to deliver, travel time to restaurant, travel time to customers, late orders, etc.). However, the law in some places dictates that the cyclists are not employees because they are not obliged to log on to the Uber app. A *Financial Times* interview of an Uber Eats worker shows that the app can change the worker's pay without notice or legal implications (O'Connor, 2016). The app initially paid £20 an hour, then it moved to £3.30 per delivery plus £1 per /mile, minus a 25 per cent "Uber service fee", plus a £5 "trip reward". The "trip reward" was subsequently cut to £4 for weekday lunch and weekend dinner deliveries, and to £3 for weekday dinner and weekend lunch deliveries.

Digital Taylorism is generally characterized by low-pay workers with a general education and no workplace who mistakenly believe that they are "their own bosses". Their contract typically transfers entrepreneurial risk from the firm to the worker. In this respect, the authority usually embodied by a boss is enforced by an algorithm that communicates with workers via smartphones. This division of labour results in the disappearance of collective and even individual labour contracts (De Stefano, 2016).

Together with this form of digital Taylorism, old forms of Taylorism are still largely in place, particularly in China. In this respect, the Foxconn case is emblematic (Ngai et al., 2015). Foxconn is one of the biggest employers worldwide and China's leading exporter. Its hiring strategy is to take advantage of the massive migration of young workers (born after 1980) from agricultural areas. It is organized as a factory-cum-dormitory (dormitory labour regime) and it employs extreme forms of control (checkpoints and 24-hour guards). The factory assumes control as a "total institution" (as defined by Foucault, 1975), controlling not only working time but human activity in its entirety. All

[17] Term used to refer to privately held start-up companies valued over US$1 billion.

[18] For a further discussion of the platform economy, see Kenney and Zysman (2016).

employees are tracked, including when they use the bathroom or eat. Physical and verbal violence is systemic in the Foxconn system. Workers are harassed and beaten on the flimsiest of pretexts. In 2010 alone, this resulted in 18 suicides. One worker took to blogging about the dehumanizing effect that the working conditions imposed by Foxconn were having on employees: "To die is the only way to testify that we ever lived ... Perhaps for the Foxconn employees and employees like us – we who are called *nongmingong*, rural migrant workers, in China – the use of death is simply to testify that we were ever alive at all, and that while we lived, we had only despair" (authors' translation from Ngai et al., 2015).

This internal hierarchical structure is matched by an international division of production and a value chain that sees Apple squeezing its suppliers, which include Foxconn. Accordingly, in order to secure contracts, Foxconn minimizes costs and transfers the pressure of low profit margins to front-line workers. Workers are paid an average wage close to the provincial minimum wage and rely massively on overtime. There is nothing especially new about this system, which applies beyond the ICT segment, in enterprises as ubiquitous as Walmart. However, such examples vividly illustrate how the application of ICT-based technologies to production may lead to forms of "turbo-Taylorism" in value-chain management that look like high-tech versions of the horrors of the factories and workhouses of the First Industrial Revolution.

Some policy scenarios, by way of conclusion

In the policy debate, recognition is finally growing that something has to be done in the face of the steep rise in inequality, the potential for massive unemployment, deteriorating working conditions and the erosion of the welfare state. The discussions tend to be partial (a one-problem-at-a-time approach), however, and are too often grounded in the interpretative paradigm of economic orthodoxy – based on market frictions, rigidities, mismatching, or at most market failures – on the presumption that, left to their own devices, markets can mostly take care of themselves efficiently, and by implication take care of all of us. So, for example, there cannot be, by construction, long-term technological unemployment.

We should, of course, assess the efficacy and possible trade-offs of alternative policy packages relating, for example, to redistributive policies, taxation in a globalized and digitalized world, education and training policies, employment policies, innovation and industrial policies; but we have to consider them together. Even more importantly, the discussion should be placed in the broader context of transformed relations between human beings and work, and between individuals and institutions. Alternative policies will result in different configurations of the State and of intermediate institutions with the spectrum ranging from lean to nanny States, from individual to collective forms of action, and from public to market-based provision of public services. All of these have starkly different implications not only in terms of income

growth but also – and equally importantly – of inclusiveness, the distribution of work and income, and ultimately power.

Alternative policies for labour market institutions include co-determination, with some workers exercising control on corporate strategies, worker ownership and, at the opposite end of the spectrum, a basic and/or universal income and minimum wage. Of course, each alternative has starkly different distributional and social implications. For example, micro-institutional engineering involving worker ownership and/or profit-sharing, or even German-type co-determination, places the burden of redistribution on the individual employer/firm and is probably quite effective at the local level, but also liable to set elite workers apart from the rest. Although it has the advantage of increasing the labour share and redistributing productivity gains at the firm level, it has the disadvantage of exacerbating inequalities across worker groups, while possibly also causing conflict between those groups and being relatively ineffective at addressing aggregate unemployment.

Conversely, the bottom of the distribution tends to be addressed by more universal schemes, such as forms of basic income. These, however, are equally controversial. While they provide a safety net for every citizen, their implementation tends to be at best neutral in terms of general income redistribution. In fact, a basic income is generally advocated together with sharp reductions in the welfare state, implying the transformation of public goods, such as health and education, into (private) income transfers. It is worth recalling that Milton Friedman was among the first proponents of the universal negative income tax. Additionally, basic income schemes may be politically biased in that the right to access them may be linked to citizenship, raising fundamental issues of discriminatory treatment vis-à-vis the pool of non-citizens. Increasing the minimum income level might also help by setting a floor for the labour share, which is in freefall. However, it might weaken unions' bargaining power and threaten the collective organization of workers. In any case, it cannot redress overall income distribution.

In that respect, taxation will continue to play a major role. New and old forms of progressive taxation should be implemented. Particular attention should be paid to understanding both the dynamics of the tax base and the ways in which different types of income, whether profits or wages, and rents (financial and non-financial) have to be taxed. Today's pro-market fury has been coupled with an anti-tax drive that has heavily reduced the redistributive impact of fiscal policies and the universal provision of services. That drive has to be reversed, and a relative balance struck in taxation rates, whereby rents and wealth should be taxed more heavily than profits, and profits more heavily than wages. It is proving increasingly difficult to capture rents and profits, not just because there is zero political will to do so but also because of their footloose nature. The technical means are there, of course, as profits, and financial flows in general, can be tracked from country of origin to country of destination – generally a tax haven.

Moreover, the subjects of taxation may also be changing. New forms of taxation, including the "robot tax", the "bit tax" and the "web tax", should at least be discussed. Some scholars suggest that he or she "who owns the robots rules the world" (Freeman, 2015). The Republic of Korea recently introduced a robot tax and the issue is also being debated in the European Parliament. However, while a robot tax is likely to slow down the adoption of labour-displacing technologies, it is still not clear whether it should be on the ownership or the use of robots. In fact, it seems much more reasonable to tax the owners. In another era, the alternative would have been tantamount to taxing the locomotives instead of the railroad tycoons. Moreover, robots can be put to very different uses, many of them aimed not at replacing but instead at complementing human activities in a wide range of fields, from agriculture to industry and the service sector (examples include medical and bio-robotic applications).

Another proposal, the "bit tax", has been part of the policy discourse since the early 1990s (Soete and Kamp, 1996). As transactions and the incomes they produce become increasingly immaterial, the tax base should shift from physical to digital units (i.e. bits of information transmitted). The web tax, which taxes digital transactions, may be considered a form of bit tax. The taxation of platforms is another open question of great relevance. Platforms are increasingly using individual assets (such as apartments in the case of Airbnb) to earn corporate profits. Additionally, distributed assets give rise to highly centralized rents.

In addition to income policies, employment policies should be considered. Some are indirect and affect the characteristics of the labour supply. Education and training policies come under this heading, as do what are known as active labour market policies, which involve training the unemployed and retraining workers so that they can overcome skills obsolescence. While certainly essential, such policies are arguably hardly sufficient and additional, more direct policies might be required (Dosi et al., 2019). Firms should not expect to hire employees trained ad hoc, but rather should be pushed to invest in enhancing employees' learning, mainly via on-the-job training schemes. In order to cope with rapid technological advances, workers should first of all possess a wide range of non-task-specific skills. In particular, a higher level of reasoning and abstract skills should be taught and developed.

An approach dating back at least to Roosevelt's New Deal holds that the State is the employer of last resort. Contrary to any notion of a lean State, this view implies the creation of massive job programmes during downturns, with the double advantage that useful jobs get done and people are provided with an income (Minsky, 1986). Last but not least, employment policies include the reduction of working hours, or at least this has been the secular tendency in industrialized countries since the mid-nineteenth century, in parallel with the long-term patterns of mechanization and automation of production. Such policies have recently been trialled in some advanced economies for the simultaneous purposes of creating new job opportunities and redistributing productivity gains. And certainly such measures ought to be matched by strong regulatory limits to involuntary part-time work, non-standard forms of employment and "mini-jobs".

The State has always been a creator of investment opportunities, a backer of long-term and risky research programmes and a herald of "mission-oriented" innovations (Mazzucato, 2013). It should double down on that role today. A fundamental objective should be to introduce policies fostering the creation of human-enhancing rather than human-replacing innovations. The order is a tall one: to develop ambitious mission-oriented programmes able to foster the emergence and widespread use of new technologies and to steer the ensuing technological trajectories. The imperatives should be environmental and social sustainability, and income redistribution. In fact, the public sector has to recover its ability not only to regulate but also to mould the strategies of private actors clearly.

We have emphasized above how information-intensive activities entail dramatically increasing returns to information itself. In turn, that tends to lead to a (quasi-)monopolistic or tight oligopolistic structure of supply – as in the cases of Google, Amazon and Airbnb, for example. How should we deal with the socio-economic consequences of such trends? Competition policies are one obvious measure, and the European Union has recently started to implement them. Will that be enough though? Probably not. History teaches that when "natural" monopolies emerge, the State needs to regulate them tightly and thoroughly, or even consider nationalizing them. In the past, this has been the case for telecommunications and other utilities. We should not shy away from such polices today in the presence of the strongest drive to monopolization since the inception of capitalism.

We are facing a historical split both in technological trajectories and in the forms of socio-economic organization. We can head towards some form of techno-feudalism with a deeply divided society, or we can go towards a society that collectively shares the benefits of technological advances. The route we take depends largely on the kinds of policy we design and implement.

References

Allen, R.C. 2017. "Lessons from history for the future of work", in *Nature*, Vol. 550, No. 7676, pp. 321–324.

—. 2009. "Engels' pause: Technical change, capital accumulation, and inequality in the British industrial revolution", in *Explorations in Economic History*, Vol. 46, No. 4, pp. 418–435.

Andrews, D.; Criscuolo, C.; Gal, P.N. 2016. *The best versus the rest: The global productivity slowdown, divergence across firms and the role of public policy*. OECD Productivity Working Papers, No. 5. Paris, OECD.

Autor, D.H. 2015. "Why are there still so many jobs? The history and future of workplace automation", in *Journal of Economic Perspectives*, Vol. 29, No. 3, pp. 3–30.

—; Levy, F.; Murnane, R.J. 2003. "The skill content of recent technological change: An empirical exploration", in *Quarterly Journal of Economics*, Vol. 118, No. 4, pp. 1279–1333.

Bárány, Z.L.; Siegel, C. 2018. "Job polarization and structural change", in *American Economic Journal: Macroeconomics*, Vol. 10, No. 1, pp. 57–89.

Baumol, W.J. 1986. *Microtheory: Applications and origins*. Cambridge, MA, MIT Press.

—. 1967. "Macroeconomics of unbalanced growth: The anatomy of urban crisis", in *American Economic Review*, Vol. 57, No. 3, pp. 415–426.

Bell, D.N.; Blanchflower, D.G. 2018. *Underemployment in the US and Europe*. NBER Working Paper No. 24927. Cambridge, MA, National Bureau of Economic Research.

Bivens, J.; Mishel, L. 2015. *Understanding the historic divergence between productivity and a typical worker's pay: Why it matters and why it's real*. EPI Briefing Paper No. 406. Washington, DC, Economic Policy Institute.

Botsman, R. 2017. "Big data meets Big Brother as China moves to rate its citizens", in *Wired*, 21 Oct. Available at: https://www.wired.co.uk/article/chinese-government-social-credit-score-privacy-invasion [accessed 22 Aug. 2019].

Braverman, H. 1974. *Labor and monopoly capital: The degradation of work in the twentieth century*. New York, NY, Monthly Review Press.

Brynjolfsson, E.; McAfee, A. 2014. *The Second Machine Age: Work, progress, and prosperity in a time of brilliant technologies*. New York, NY, W.W. Norton & Company.

Calvino, F.; Virgillito, M.E. 2018. "The innovation-employment nexus: A critical survey of theory and empirics", in *Journal of Economic Surveys*, Vol. 32, No. 1, pp. 83–117.

Casilli, A.A. 2017. "Digital labor studies go global: Toward a digital decolonial turn", in *International Journal of Communication*, Vol. 11, pp. 3934–3954.

Cirillo, V.; Rinaldini, M.; Staccioli, J.; Virgillito, M.E. 2018. *Workers' intervention authority in Italian 4.0 factories: Autonomy and discretion*. LEM Working Papers Series, No. 13. Pisa, Laboratory of Economics and Management, Institute of Economics, Scuola Superiore Sant'Anna.

Clark, C. 1957. *The conditions of economic progress*. Third edition. London, Macmillan.

Dabla-Norris, E.; Kochhar, K.; Suphaphiphat, N.; Ricka, F.; Tsounta, E. 2015. *Causes and consequences of income inequality: A global perspective*. IMF Staff Discussion Note No. 13. Washington, DC, International Monetary Fund.

David, P.A. 1985. "Clio and the economics of QWERTY", in *American Economic Review*, Vol. 75, No. 2, pp. 332–337.

De Stefano, V. 2016. "The rise of the just-in-time workforce: On-demand work, crowdwork, and labor protection in the 'Gig-Economy'", in *Comparative Labor Law & Policy Journal*, Vol. 37, No. 3, pp. 471–504.

Dosi, G. 1984. "Technology and conditions of macroeconomic development", in C. Freeman (ed.): *Design, innovation and long cycles in economic development*. London, Design Research Publications, pp. 99–125.

—. 1982. "Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change", in *Research Policy*, Vol. 11, No. 3, pp. 147–162.

—; Freeman, C.; Fabiani, S. 1994. "The process of economic development: Introducing some stylized facts and theories on technologies, firms and institutions", in *Industrial and Corporate Change*, Vol. 3, No. 1, pp. 1–45.

—; Gambardella, A.; Grazzi, M.; Orsenigo, L. 2008. "Technological revolutions and the evolution of industrial structures: Assessing the impact of new technologies upon the size and boundaries of firms", in *Capitalism and Society*, Vol. 3, No. 1, pp. 1–49.

—; Marengo, L. 2015. "The dynamics of organizational structures and performances under diverging distributions of knowledge and different power structures", in *Journal of Institutional Economics*, Vol. 11, No. 3, pp. 535–559.

—; Nelson, R.R. 2010. "Technical change and industrial dynamics as evolutionary processes", in B. Hall and N. Rosenberg (eds): *Handbook of the economics of innovation*. Vol. 1. Amsterdam, North-Holland/Elsevier, pp. 51–127.

—; Pereira, M.C.; Roventini, A.; Virgillito, M.E. 2019. "What if supply-side policies are not enough? The perverse interaction of flexibility and austerity", in *Journal of Economic Behavior & Organization*, Vol. 162, pp. 360–388.

—; —; —; —. 2018a. "Causes and consequences of hysteresis: Aggregate demand, productivity, and employment", in *Industrial and Corporate Change*, Vol. 27, No. 6, pp. 1015–1044.

—; —; —; —. 2018b. "The effects of labour market reforms upon unemployment and income inequalities: An agent-based model", in *Socio-Economic Review*, Vol. 16, No. 4, pp. 687–720.

—; Virgillito, M.E. 2017. "In order to stand up you must keep cycling: Change and coordination in complex evolving economies", in *Structural Change and Economic Dynamics*. Available at: https://doi.org/10.1016/j.strueco.2017.06.003 [accessed 27 Nov. 2019].

—; Yu, X. 2018. "Technological catching-up, sales dynamics, and employment growth: Evidence from China's manufacturing", in *Industrial and Corporate Change*, Vol. 28, No. 1, pp. 79–107.

Ford, M. 2015. *The rise of the robots: Technology and the threat of mass unemployment*. New York, NY, Basic Books.

Foucault, M. 1975. *Surveiller et punir: Naissance de la prison*. Paris, Gallimard [translated into English as: *Discipline and punish: The birth of the prison*. New York, Pantheon Books, 1997].

Franzini, M.; Pianta, M. 2015. *Explaining inequality*. London, Routledge.

Freeman, C. 2019. "History, co-evolution and economic growth", in *Industrial and Corporate Change*, Vol. 28, No. 1, pp. 1–44.

—. 1992. *The economics of hope: Essays on technical change and economic growth and the environment*. London, Pinter Publishers.

—; Clark, J.; Soete, L. 1982. *Unemployment and technical innovation: A study of long waves and economic development*. London, Pinter Publishers.

—; Perez, C. 1988. "Structural crises of adjustment: Business cycles and investment behaviour", in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds): *Technical change and economic theory*. London, Pinter Publishers, pp. 38–66.

—; Soete, L. 1994. *Work for all or mass unemployment? Computerised technical change into the 21st century*. London, Pinter Publishers.

Freeman, R.B. 2015. "Who owns the robots rules the world", in *IZA World of Labor*, Vol. 5. Available at: https://wol.iza.org/uploads/articles/5/pdfs/who-owns-the-robots-rules-the-world.pdf [accessed 27 Aug. 2019].

—. 1980. "Unionism and the dispersion of wages", in *ILR Review*, Vol. 34, No. 1, pp. 3–23.

Gordon, R.J. 2012. *Is US economic growth over? Faltering innovation confronts the six headwinds*. NBER Working Paper No. 18315. Cambridge, MA, National Bureau of Economic Research.

Gordon, C.; Eisenbrey, R. 2012. "As unions decline, inequality rises", in *Economic Snapshot*, 6 June. Washington, DC, Economic Policy Institute. Available at: https://www.epi.org/publication/unions-decline-inequality-rises/ [accessed 13 Aug. 2017].

Groshen, E.L.; Potter, S. 2003. "Has structural change contributed to a jobless recovery?", in *Current Issues in Economics and Finance*, Vol. 9, No. 8, pp. 1–7.

Hilferding, R. 1910. *Das Finanzkapital. Eine Studie über die jüngste Entwicklung des Kapitalismus*. Vienna, Wiener Volksbuchhandlung [translated into English as: *Finance capital: A study of the latest phase of capitalist development*. London, Routledge and Kegan Paul, 1985].

Hirsch, F. 1976. *Social limits to growth*. Cambridge, Harvard University Press.

Hutchinson, J.; Persyn, D. 2012. "Globalisation, concentration and footloose firms: In search of the main cause of the declining labour share", in *Review of World Economics*, Vol. 148, No. 1, pp. 17–43.

Huws, U. 2014. *Labor in the global digital economy: The cybertariat comes of age*. New York, NY, Monthly Review Press.

Jaimovich, N.; Siu, H.E. 2012. *Job polarization and jobless recoveries*. NBER Working Paper No. 18334. Cambridge, MA, National Bureau of Economic Research.

Jaumotte, F.; Buitron, C.O. 2015. *Inequality and labor market institutions*. IMF Staff Discussion Note No. 14. Washington, DC, International Monetary Fund.

Karabarbounis, L.; Neiman, B. 2014. "The global decline of the labor share", in *Quarterly Journal of Economics*, Vol. 129, No. 1, pp. 61–103.

Kenney, M.; Zysman, J. 2016. "The rise of the platform economy", in *Issues in Science and Technology*, Vol. 32, No. 3, pp. 61–69.

Keynes, J.M. 1931. “Economic possibilities for our grandchildren”, in J.M. Keynes (ed.): *Essays in persuasion*. London, Macmillan [London, Palgrave Macmillan, 2010, pp. 321–332].

Kuznets, S. 1955. “Economic growth and income inequality”, in *American Economic Review*, Vol. 45, No. 1, pp. 1–28.

Landes, D.S. 1969. *The unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present*. Cambridge, Cambridge University Press.

Lazonick, W. 2014. “Profits without prosperity”, in *Harvard Business Review*, Sep., pp. 46–55.

—; Mazzucato, M. 2013. “The risk-reward nexus in the innovation-inequality relationship: Who takes the risks? Who gets the rewards?”, in *Industrial and Corporate Change*, Vol. 22, No. 4, pp. 1093–1128.

Lenin, V.I. 1917. *Империализм как высшая стадия капитализма*. Petrograd, Zhizn i znanie [translated into English as: *Imperialism, the highest stage of capitalism: A popular outline*. London, Lawrence and Wishart, 1939].

Marcolin, L.; Miroudot, S.; Squicciarini, M. 2019. “To be (routine) or not to be (routine), that is the question: A cross-country task-based answer”, in *Industrial and Corporate Change*, Vol. 28, No. 3, pp. 477–501.

Mazzucato, M. 2013. *The entrepreneurial state: Debunking public vs. private sector myths*. London, Anthem Press.

Milanovic, B. 2016. *Global inequality: A new approach for the age of globalization*. Cambridge, MA, Harvard University Press.

Minsky, H.P. 1986. *Stabilizing an unstable economy: The lessons for industry, finance and government*. New Haven, CT, Yale University Press.

Moretti, E. 2012. *The new geography of jobs*. New York, NY, Houghton Mifflin Harcourt.

Moro, A.; Rinaldini, M.; Staccioli, J.; Virgillito, M.E. 2019. “Control in the era of surveillance capitalism: An empirical investigation of Italian Industry 4.0 factories”, in *Journal of Industrial and Business Economics*, Vol. 46, No. 3, pp. 347–360.

Ngai, P.; Huilin, L.; Yuhua, G.; Yuan, S. 2015. *Nella fabbrica globale: Vite al lavoro e resistenze operaie nei laboratori della Foxconn*. Verona, Ombre Corte.

Nuvolari, A. 2002. “The ‘machine breakers’ and the industrial revolution”, in *Journal of European Economic History*, Vol. 31, No. 2, pp. 393–426.

O’Connor, S. 2016. “When your boss is an algorithm”, in *Financial Times*, 8 Sep. Available at: https://www.ft.com/content/88fdc58e-754f-11e6-b60a-de4532d5ea35 [accessed 21 Aug. 2019].

Pasinetti, L.L. 1981. *Structural change and economic growth: A theoretical essay on the dynamics of the wealth of nations*. Cambridge, MA, Cambridge University Press.

Ricardo, D. 1821. *On the principles of political economy and taxation*. Third edition. London, John Murray.

Rousseau, J.-J. 1755. *Discours sur l’origine et les fondements de l’inégalité parmi les hommes*. Amsterdam, Marc-Michel Rey [translated into English as: *A discourse on inequality*, London, Penguin Books, 1984].

Schwellnus, C.; Kappeler, A.; Pionnier, P.-A. 2017. *Decoupling of wages from productivity: Macro-level facts*. Economics Department Working Papers, No. 1373. Paris, OECD.

Smith, A. 1776. *An inquiry into the nature and causes of the wealth of nations*. London, Strahan and Cadell.

Soete, L.; Kamp, K. 1996. “The ‘Bit Tax’: The case for further research”, in *Science and Public Policy*, Vol. 23, No. 6, pp. 353–360.

Stiglitz, J.E. 2002. *Globalization and its discontents*. New York, NY, Norton.

Syverson, C. 2017. “Challenges to mismeasurement explanations for the US productivity slowdown”, in *Journal of Economic Perspectives*, Vol. 31, No. 2, pp. 165–186.

Timmer, M.P.; Erumban, A.A.; Los, B.; Stehrer, R.; de Vries, G.J. 2014. “Slicing up global value chains”, in *Journal of Economic Perspectives*, Vol. 28, No. 2, pp. 99–118.

UNCTAD. 2018. *Trade and Development Report 2018: Power, platforms and the free trade delusion*. Geneva.

Vivarelli, M. 2014. "Innovation, employment and skills in advanced and developing countries: A survey of economic literature", in *Journal of Economic Issues*, Vol. 48, No. 1, pp. 123–154.

Womack, J.P.; Daniel, T.J.; Roos, D. 2007. *The machine that changed the world*. New York, NY, Free Press.

Zuboff, S. 2015. "Big other: Surveillance capitalism and the prospects of an information civilization", in *Journal of Information Technology*, Vol. 30, No. 1, pp. 75–89.