Chapter for K. Zimmermann (ed.)
Handbook of Labor, Human Resources and Population Economics, Springer, 2019

Technology and work. Stylized facts for the digital age

Mario Pianta
Scuola Normale Superiore
Classe di Science Politico-Sociali
Firenze, Piazza Strozzi
mario.pianta@sns.it

Abstract

The complex relationships between technology and employment can be summarised in a set of stylized facts – based on extensive research results - that describe the process of technological change, the nature of digital technologies, the impact on the quantity and quality of jobs, on skills and wages. In short, we can argue that technology is shaped by social relations and that in the digital age the nature of economic activity and work is deeply changing. The aim of innovation has long been to save human labour, with the potential to create technological unemployment, but different technological strategies have contrasting employment effects, that may be investigated at the firm, industry and macroeconomic levels, with industries showing different employment dynamics associated to the broader process of structural change and international production. The dynamics of technological change can hardly be understood with an equilibrium view of the economy, as growth dynamics, catching up, demand patterns, structural change and business cycles play a major role in shaping the impact of technology. Labour markets conditions are relevant, but the impact of technology on jobs requires a broader frame of analysis, including the economic structure and social relations, the institutional setting and policy choices. New technologies tend to have a differentiated impact across occupations and skills and they are often an engine of inequality; profits benefit more than wages, and wage disparities increase. Public policies are needed to address the variety of economic and social challenges associated to the evolution of technologies, digitalisation and their impact on jobs and wages.

Introduction

Technological change is a major driver of economic development, shapes a wide range of economic and social activities, deeply affects the quantity and quality of jobs and the way work is organised. The rise of digital technologies has introduced major changes and is having a large impact on the economy and society. In this chapter I focus on the relationships between technology and employment providing a set of stylized facts for understanding the process of technological change, the nature of digital technologies, the impact on the quantity and quality of jobs, on skills and wages.
This chapter - that summarises and updates a previous article (Pianta, 2018) - highlights current trends, conceptual issues, methodological approaches and research results, building on a large amount of empirical research (Vivarelli and Pianta, 2000; Pianta, 2005; Bogliacino and Pianta, 2010; Bogliacino et al., 2011; Cirillo et al. 2018; Franzini and Pianta, 2016; Coveri and Pianta 2019; Reljic et al. 2019).

Technology is shaped by social relations; digital technologies are transforming capitalism. Technology does not 'fall from the sky', it is not 'neutral'. It is a social construction largely shaped by the logic of capitalism and by power relations in society. Scientific advances and human knowledge offer opportunities for technological innovation that may lead a nation's economy and individual firms in very different directions. Research and innovation efforts at the technological 'frontier' are combined with the adoption, adaptation and diffusion of already available knowledge and technologies, shaping a country's growth trajectory and social dynamics. Large firms and major public policy actors play a key role in decisions about the research and adoption of new technologies; the choices that are made tend to be associated with a search for greater capital accumulation, control and power.

The most appropriate concept for understanding the economic role of technology is that of techno-economic paradigm (Perez, 1983, Freeman and Louca, 2001). Building on the work of Kondratieff and Schumpeter, we can argue that capitalist development is characterised by a succession of techno-economic paradigms based on a cluster of core technologies with a major diffusion potential across the economy and with rapidly reducing costs. Steam power and the textile machines of the Industrial revolution were the key elements of the first techno-economic paradigm; the present one has emerged in the 1980s and is based on Information and Communication Technologies (ICTs), with the current acceleration in digitalisation, networks and automation of production.

Mainstream views on digitalisation have emphasised the 'inevitability' and potential benefits (mainly for users) of such developments. In the European context much attention is devoted to the 'Industry 4.0' perspective where large firms and government policies invest in accelerating digitalisation and automation of manufacturing and services, with important efforts in robotisation, 'Big Data', 'Internet of things', 'Cloud computing' and 'platform economy'. This model of digitalisation and automation raises major challenges to the future of work in terms of fewer jobs and more polarised occupations, changing requirements for education and faster obsolescence of knowledge, weaker union protection and greater inequality.

Some concerns on the employment impact have emerged. A rather impressionistic study estimated that within the next 20 years 47% of jobs could be automated in the United States (Frey and Osborne 2017). The impact of robots – assumed to be competitors with workers – could be significantly negative for employment and wages (Acemoglu and Restrepo, 2017).

It is possible, however, to look inside the 'black box' of digitalisation and investigate more carefully its key drivers. Two main dimensions of digitalisation have been identified (Reljic et al. 2019). On the one hand there is the use by industries and firms of intermediate inputs from digital-intensive sectors (electronics, software services etc.); this reflects the diffusion of inputs based on ICT goods and services that have the potential to improve the performance of other industries, being incorporated in product innovations and contributing to higher quality activities. On the other hand there is the investment by industries and firms in tangible and intangible ICT assets – computer hardware and software, telecommunication equipment and databases – that become part of the capital stock. In an analysis of European industries these two dimensions of digitalisation have been found to have contrasting employment effects. When industries acquire from digital sectors greater intermediate inputs, they are able to increase performances and jobs; digital inputs operate in a similar way, and appears to be complementary to product innovations and to changes in organisations. When digital investments per employee increase, job reductions emerge, with an impact similar and complementary to innovation in processes, allowing the restructuring of production activities with greater efficiency, control and flexibility, and with fewer workers. In terms of quantity of jobs, digitalisation appears to have contributed to the overall reduction of employment in European industries. In terms of quality of jobs, digitalisation appears to contribute to a more polarised occupational structure (Reljic et al. 2019).

Besides this overall impact, digitalisation is introducing major changes in the way work is organised, in labour relations, in workers' responses and adaptation to automation, in learning processes and organizational routines (a summary of studies in these areas is in Cirillo and Molero Zayas 2019).

But the impact of digitalisation is not limited to the way economic activities are organised. In fact, digitalisation is changing the boundaries between market and non-market goods, between private and public goods, between work and (unpaid) human activities, between waged employment and other forms of (somehow paid) work. AirB&B is turning a spare room in the house from a gift to a friend into a market good to be sold, requiring a new type of 'self-employed' work mixed with social interaction. Some market goods have been replaced by non market activities, with job destruction on the one hand, and free access to improved goods and services on the other hand – the creation of knowledge as a public good in Wikipedia is carried out by unpaid on-line cooperative efforts, as opposed to paid work for producing and selling the Encyclopaedia Britannica. Leisure-type communication by individuals has been turned by companies such as Facebook into a profitable activity exploited for advertising and market services. As new digital platforms emerge organising work for thousands of people – such as Uber for driving services - the nature of work changes, with an appearance of occasional 'self-employment' and a reality of complete control by the platform corporation.

A far-sighted view has pointed to a deeper transformation of the economy and society in the digital age - the rise of 'surveillance capitalism' (Zuboff 2019). The main players of this model of capitalism – Google, Facebook, etc. – have built world monopoly positions in information-related activities, in key areas of human interaction, offering 'free' services to users but capturing systematic knowledge on their activities and behaviour. The logic of 'surveillance capitalism' has become the extraction of all available information from individuals, the prediction and influence of their behaviour – as consumers, workers and citizens – the selling of this information to businesses tailoring their supply to specific consumer profiles, the organisation of global platforms where novel models of flexible work organisation can be developed. With a monopolistic power at the world level and ever extending activities in new fields of human interaction, the profit potential of this model of capitalism is huge, and the financial system has promptly recognised this, with an extreme rise in the capitalisation value of major digital firms. In parallel, the actual production of goods and services – that requires the employment of workers - has taken second place in this model, left to industries and countries outside the 'digital core' of the world economy.

The result is that at the end of 2016 the market capitalisation of Google reached 532 billion dollars while the company had 75,000 US employees; that of Facebook reached 332 billion with 18,000 US employees. This is in contrast with 'Fordist' times when General Motors reached the peak of its market capitalisation in 1965 at 225 billion having at the time 735,000 employees (Zuboff, 2019, p.500). In industrial capitalism large firms dominated markets and finance, but at the same provided jobs and wages that allowed workers to consume the goods the companies produced. This 'reciprocity' is lost in 'surveillance capitalism', where the dominant firms do not need anymore consumers for their profits, as they main customers are businesses intending to influence individuals' behaviour; the demand constraint is also disappearing as new areas of human activities are invested by digitalisation and their range of operation is extended to the whole world.

The global reach of major digital firms, the immaterial nature of their activities and the network structure of interactions means that stronger firms can increasing their market power, industry concentration and profits, saving jobs and lowering the labour share (Autor et al. 2017) and that business can be rapidly expanded - 'hyperscaled' (Chui and Manyika 2015) – without a parallel expansion of employment. With such processes, the employment requirements of 'surveillance capitalism' appear to be very different from those of industrial production; the rapid expansion of digital activities can occur without a large growth in the demand for labour, at least in more advanced countries. What is emerging is a digital economy that is reaping large financial profits but not creating jobs, that is employing a small number of highly qualified managers and professionals, but hiring few unskilled workers with low wages. The prospect is that of an economy with extreme asymmetries in power, and a society with extreme unemployment and inequality. As information is at the core of digital technologies, a major source of asymmetry concerns the concentration of knowledge that dominant firms obtain. In this way the uncertainty that is typical of the operation of markets with a large number of agents is replaced by the full knowledge, concentrated in few monopolists, of

information on how individuals may act, with a pervasive capability to influence their behaviour and economic outcomes.
These transformations are changing the nature of capitalism; but they also aim to constrain human nature, the freedom and ability to act, and represents a major challenge to democracy. Zuboff argues that "surveillance capitalism annexes human experience to the market dynamic so that it is reborn as behaviour" (ibid. p.514). Human experience becomes a new commodity shaping the new age of capitalism in the same way as – in Karl Polanyi's analysis (Polanyi 2001) - the transformation in commodities of land, labour and money were crucial for the rise of industrial capitalism.
While the analysis of Zuboff (2019) may appear at times to generalise the case of few dominant digital firms, it is extremely important that the economic, social and political consequences of the rise of digitalisation be addressed with appropriate public policies and regulations. As it has happened in the past at the rise of previous techno-economic paradigms, today key decisions on the evolution of digital technologies, on the way dominant firms operate, on the way the benefits of digital technologies are distributed in society have to become the object of national (and global) policy debates and democratic political processes, reversing the power of digital monopolists and preventing the rise of 'surveillance capitalism'.

Technology saves human labour; technological unemployment is rooted in capitalist production. The history of technology is made of efforts for expanding human capabilities, replacing harder tasks and saving labour. In capitalism technology is embodied in the means of production and in the knowledge of workers. Since the industrial revolution of the XIX century, capitalism has developed machines and technologies that could replace human labour, reducing wage costs, accumulating capital and generating more profits. Technological unemployment is therefore a process rooted in the nature of capitalist production.
For two centuries, a major positive effect of technological change has been reducing the quantity of human labour required by economic activity. The average annual working time of workers has rapidly declined; in the last three decades, however, this reduction has stopped and has been reversed in many countries. Instead of distributing the benefits of innovation and productivity gains in terms of shorter working hours for all – with constant wages – we have less people working longer hours, while unemployment is high. Previous declines in working hours were the outcome of social conflict and political decisions, creating complex institutional arrangements and social rules regulating the use of labour.
The debate on these issues started with the industrial revolution. Adam Smith linked the invention of machines to the division of labour and emphasized its labour saving effects. The optimism of Classical economists in the early XIX century contrasted with the impoverishment of the English working classes – industrial workers, small artisans, and displaced peasants – who had started to organize trade unions and to launch Luddite struggles against the job losses and deskilling brought about by mechanization. David Ricardo was convinced that the economy could compensate the negative employment effects, but in a passage in the chapter "On machinery", added in the third edition of his Principles of Political Economy and Taxation, argued that "The opinion, entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy" (Ricardo, 1951:392).
Karl Marx emphasized the losses for workers in terms of jobs, skills, wages, and control over their work resulting from the way mechanization was proceeding and argued that unemployment grows as technical change displaces labour more rapidly that the accumulation of capital demands new workers. Marx viewed capital accumulation as a constant search for new production techniques and new products (a key starting point for the work of Schumpeter). High unemployment assures lower wages and greater control over workers; along this road, however, capital accumulation ultimately encounters the problems of finding adequate markets and demand (Heertje, 1973; Vivarelli, 1995, 2014; Pianta, 2005). Marx's argument that capitalism has a tendency to take the control of the labour process away from workers and transfer it to machines, expanding the power of capital over labour

has been made again by Harry Braverman (1974) in the context of Fordist-type mass production in the US, where a 'degradation of work' could be identified.
In the age of Information and Communication Technologies the potential for enriching or deskilling work has greatly expanded, but management has often introduced new technologies and shaped work organisation with the primary aim to reduce labour and increase control over workers (Shaiken, 1984, Noble, 1984). Brynjolfson and McAfee (2014, p.10-11) argued that "rapid and accelerating digitization is likely to bring economic (...) disruption, stemming from the fact that as computers gets more powerful, companies have less need for some kinds of workers. Technological progress is going to leave behind some people, perhaps even a lot of people, as it races ahead".
The actual outcomes on the quantity and quality of work and on technological unemployment have to be investigated in particular times and places and depend on growth models, social relations, institutional arrangements on jobs and working time and on the broader policy frameworks of countries.

Different technological strategies have contrasting employment effects in firms, industries and economies. There is too much talk of an undifferentiated 'technology' – affecting us all in a deterministic way – and not enough attention to the different technological strategies pursued by different actors pushing knowledge and its applications in sometimes diverging directions – just think of innovations in solar energy as opposed to coal and fracking technologies. Within a given firm, technology could mean – in Schumpeter's distinction - the introduction of new products, new processes, new forms of organisation. We have an innovation when a firm first markets a new product or introduces a new process; the road open to followers in the same industry (in other countries, too) is the imitation of new products (perhaps with incremental improvements, and adaptation to new users' needs); firms in all sectors may decide on the adoption of new processes or use of new (intermediate) products generated in other industries (and/or countries). The latter two lead to the diffusion of innovations throughout the economy, in both production and consumption.
These types of innovation greatly differ in their nature, economic relevance and labour market impact. Product innovations (in both manufacturing and service industries) can be based on internal innovative activities as well as on the acquisition of new intermediate or capital goods. They may replace old products or may be designed in order to reduce costs, with little or no net effect on employment, skills and wages. On the other hand, new products meeting a demand with high elasticity may expand output, leading to job creation; may increase variety and quality, leading to skill upgrading; both developments may turn a part of the productivity increases into higher wages.
Process innovations (including those in the delivery of services) usually replace labour with capital (often with new investment based on information and communication technologies), leading to efficiency gains and job losses. When the new products are investment goods, they represent a product innovation in the industries producing them, and process innovations in the industries acquiring them, with contrasting effects on jobs. This heterogeneity of innovation can be summarised in contrasting technological strategies (Pianta, 2001, 2005):
a. a strategy of *technological competitiveness* where firms or industries carry our R&D, introduce new products, open up new markets, searching for quality and technological advantages; this may result in job creation (if new products are not simply a substitution of old ones);
b. a strategy of *active cost (or price) competitiveness* where new processes and organisations are introduced with the aim to replace labour, reduce costs, restructure production and improve price competition; this generally results in job losses.
In order to identify this heterogeneous technological strategies, however, empirical analyses have to move beyond the use of R&D, patent data or the or the adoption of ICTs as technological indicators and use data from innovation surveys on firms, that are now available not only for Europe, but also for a large number of emerging countries. Innovation surveys - based on the OECD-Eurostat Oslo Manual and on the Bogota Manual (OECD 2018) - provide information based on surveys that are representative of the universe of firms that document the presence of innovation in products, processes and organisations; the expenditure for innovation (R&D, design, new machinery,

marketing, etc.); the objectives that are pursued (from opening up new markets to reducing labour costs); the barriers to innovation; the share of sales associated to new products and their degree of novelty (new for the firm only or new for the relevant market); the relevance of policies, and many other aspects.

By using this approach it is possible to break down the view of an undifferentiated technology affecting employment and to test the contrasting employment effects of strategies of technological or cost competitiveness. A large evidence is now available on European countries showing that manufacturing and service industries where product innovation is important have positive employment effects. Conversely, labour saving cost competitiveness efforts lead to job losses (Pianta, 2000; Bogliacino and Pianta, 2010).

Industries differ in their employment dynamics and role of technology. Some expand and some decline, and technology usually plays a role. The high-tech/low-tech distinction and – in a more refined way – the Pavitt taxonomy of industries (Pavitt, 1984; Bogliacino and Pianta, 2010) provide useful ways for differentiating this evolution. The empirical evidence shows that industries with higher technological activities tend to show better employment performances, although with many exceptions in particular countries and periods. Moreover, in different industry groups the innovation-employment relationship tends to take different forms, with the job-creating effect of new products stronger in science based industries and the job-destroying effect of new processes stronger in traditional, low-technology industries.

The employment impact of technology can be investigated at the firm, industry and macroeconomic levels. Product innovation tends to have a positive job creating effect at all levels. Firms innovating in both products and processes, however, may be successful in expanding output and jobs, but often do so at the expense of non-innovating firms, with little net job creation. Industry and aggregate studies generally point out the possibility of technological unemployment, which emerges when industries or countries see the prevalence of process innovations in contexts of weak demand and low entry of new firms. Studies on the whole economy may take into account the "compensation mechanisms" (decrease in prices, new machinery, etc.) that may create new jobs elsewhere in the economy, thus reducing the negative effects of technology on jobs (Vivarelli, 1995). However, the importance of oligopolistic power in high technology industries may limit some of these effects (Sylos Labini, 1969).

In an open economy innovation may lead to competitiveness and exports, weakening the demand constraint or, conversely, domestic demand may increase imports when foreign competitors are more innovative in terms of price or quality; the job destroying effects of technology tend to be intertwined to those of offshoring of domestic production (Bramucci et al., 2017).

Technological change is a disequilibrium process; evolution, demand and economic structure matter. Mainstream economics is based on an equilibrium view of product and labour markets; technology is generally viewed as an exogenous factor affecting production processes; after a technology shock price and wage adjustments are expected to lead to a new labour market equilibrium. New growth theory has improved on this approach by assuming that in some firms innovation is endogenous and its effects spill over to the rest of the economy. Under these assumptions there is little room for understanding technological change and its employment effect. Conversely, disequilibrium approaches, combining Neo-Schumpeterian and evolutionary insights with the post-Keynesian perspective on the key role of demand and structural change provide the most appropriate tools for understanding innovation and its employment impact.

a. *Neo-Schumpeterian approaches* have developed the concept of techno-economic paradigms, associated to long waves of capitalist developments. The rise of the paradigm based on Information and Communication Technologies creates and destroys a large amount of jobs; employment expansion can be expected only once the mismatches between the new technologies and the old economic and social structures and institutions are overcome, with a two-way adjustment. Innovation has to be adapted to social needs and economic demands; economic and social structures evolve under pressure from new technologies. New technologies need to be matched by organizational changes,

new institutions and rules, learning processes, the emergence of new industries and markets, and the expansion of new demand. A long adjustment process is required and persisting mismatches can lead to unemployment (Freeman, Clark and Soete, 1982; Freeman and Soete, 1987; 1994; Freeman and Louçã, 2001).

b. *Evolutionary perspectives* have argued that technologies improve through innovations that expand variety and through selection in market processes; the emphasis is put on change rather than equilibrium and the role of heterogeneity, path dependency, feedbacks loops is emphasised. As analytical tools simulation and models based on heterogeneous interacting agents are often used (Nelson and Winter, 1982; Dosi et al. 1988).

c. *Post-Keynesian views of structural change* emphasise the importance of demand in driving economic growth and the importance of a country's sectoral structure; industries are assumed to grow or decline on the basis of the joint evolution of technology on the one hand and demand on the other (Pasinetti, 1981). A strong expansion of demand – both domestic and foreign – offers room for creating new economic activities and jobs alongside the job destruction resulting from technology; new products tend to be introduced in phases of expansion when they can more easily meet new demand. A country's success in job creation, however, also depends on its economic structure, reflecting the relative importance of high and low tech activities and the type of innovations that are introduced (Bogliacino et al. 2013).

The process of structural change, with countries' different abilities to contract declining industries and expand production and employment in emerging ones plays a major role in explaining employment performances. Better outcomes are found in countries with a greater activity in sectors with fast growing (at the world level) demand and output, and with greater ability to reshape their economic structures. Worse outcomes are found where a larger part of employment is in industries more exposed to the negative impact of labour-saving technological change and globalization, and where more rigidities exist in the economic structure.

This appears to be the case of many European countries, especially in Southern Europe. In the conclusions of our book '*The employment impact of innovation'*, writing in 2000, before the introduction of the euro, we wrote that "within the European Union, the current constraints on the expansion of demand, set by the terms of the European Economic and Monetary Union may turn out to be serious factors preventing the evolution of economic structures towards a direction more consistent with the potential offered by technological change" (Pianta and Vivarelli 2000, p. 211). The low economic and employment growth of Europe since then – and in particular after the 2008 crisis – confirms how important an expansionary macroeconomic policy is in order to capture the potential employment benefits of technology.

The global crisis of 2008 has brought attention back to the importance of business cycles. Schumpeterian insights have long stressed the connection between technology and business cycles. Both innovation patterns and jobs are affected by upswings and downswings. Expansions provide space for new products, new markets, new jobs; recessions bring new processes, restructuring and job destruction. The nature of the innovation-employment relationship changes from the upswing to the downswing of the cycle. Periods of major crises – such as the years since 2008 in Europe – are moments of major structural change when weaker firms and industries disappear, new labour saving processes are introduced leading to the loss of large numbers of low skill jobs. Only when new demand starts an upswing in the business cycle, the opportunities for introducing new products open up again, bringing with them new job creation (Mensch 1979; Freeman and Louçã 2001; Lucchese and Pianta 2012).

In emerging countries employment outcomes are jointly affected by technology and catching up. The construction of technological capabilities is a crucial component of the development process; it can be achieved through the acquisition and adaptation of foreign technologies; participation in global production networks organised by multinational firms; development of a domestic knowledge base and innovative potential.

In emerging countries the employment impact is driven by complex and contrasting forces; overall growth dynamics drives job creation; the acquisition of foreign machinery may introduce the same

labour saving bias found in advanced countries; once emerging countries reach some technological capability they may enter export markets with a large potential for job creation; catching up in productivity levels may reduce employment; achieving independent capabilities in selected fields may open up the possibility to reap the job creating benefit of product innovation. For many emerging countries the availability of innovation surveys comparable to European ones has made it possible to document the diversity of technological strategies that are carried out (Bogliacino et al. 2011).

The impact of technology is different across occupations and skills. Technologies are not all the same, nor jobs are. The *quality* of jobs – in terms of occupations, skills, educational levels, etc. -has to be considered when we investigate changes in employment. Contrary to long held expectations of a technology-driven upskilling of work from blue collar to white collar jobs (*skill bias technical change*) (Autor et al. 1998; Berman et al. 1998; Acemoglu 2002; Acemoglu and Restrepo 2017), what is emerging in most countries and industries is a more polarised employment structure, with larger numbers of managers, professionals and technicians, and more unskilled manual workers, especially in services (Eurofound 2013; Card and Mas 2016; Cirillo 2016; Cirillo et al, 2018).
This trend also emerges when we look at the nature of 'tasks' performed (*routine biased technical change*) distinguishing between routine jobs – both cognitive and manual (such as those of clerks and factory workers) – that are easier to replace with computers, and non-routine activities (such as those of those of managers and gardeners) (Goos and Manning 2007; Goos et al. 2014).
In this analysis, however, attention should be paid to the hierarchies in place – in terms of power, control over work and remuneration. The occupational structure (based on the ISCO classification of jobs) sheds more light on current change than a focus on 'tasks'. Industries with greater innovative potential are characterised by higher occupations (managers, professionals and technicians), while those where manual workers constitute the bulk of the workforce have the lowest technological activities. Each occupational group is differently affected by innovation and other factors of change. Managers are the group that is most favoured by the introduction of product innovations, while process innovations negatively affect the jobs of low skill workers. The impact of offshoring is parallel to the one of process innovation, with negative effects especially for low skill workers. If we investigate the different effects during the business cycle, we find that the gains in the expansion are concentrated in managers, while in the recession the largest losses hit craft and manual workers (Cirillo 2016; Cirillo et al. 2018).
These developments are the current manifestation of a fundamental characteristic of capitalism – its tendency to introduce technology in ways that allow less skilled (and lower paid) labour to be used. The emergence of a more polarised occupational structure has major implications for educational requirements and welfare policies, and is likely to be problematic in terms of wage levels, inequality and prospects for social mobility.
In recent decades this polarisation of the employment structure has gone hand in hand with a set of labour market 'reforms' that have greatly increased the precarisation of labour, reduced the coverage of national labour contracts, lowered employment protection regulations and limited the power of trade unions. The 2015 International Labour Office report has documented the rise of non-standard jobs and has showed that "over 6 out of 10 wage and salaried workers worldwide are in either part-time or temporary forms of wage and salaried employment. Women are disproportionately represented among those in temporary and part-time forms of wage and salaried employment" (ILO, 2015, p.13). These policies were introduced with the goal to increase 'flexibility', assuming – as mainstream approaches do - that efficient and flexible labour markets can reduce unemployment. While labour market conditions and institutions are relevant, employment outcomes are not determined in labour markets alone, but rather they depend on aggregate demand in the product markets and on the strategies of firms concerning technology and international production.

Technology is an engine of inequality; profits benefit more than wages, wage disparities increase. Income inequality has reached record levels in most advanced and emerging countries and is now a major economic and political challenge. In the last three decades in many economies national

income has experienced a shift of 10 to 15 percentage points from wages to profits; productivity growth is leaving behind wage growth; poverty rates increase (Franzini and Pianta 2016; Piketty, 2013). The way technology has driven economic change is part of the problem; new product and markets allow large profits; new processes lead to job losses and lower wages; more precarious jobs and lower employment protection reduce labour costs; digital platforms allow new forms of low-wage work outside labour contracts. In most countries policies – on technology, trade, industry, labour markets, taxation, welfare expenditure, etc. - have favoured such increase in disparities, resulting in major economic and political problems.

In a study of the parallel determinants of wages and profits in manufacturing and service industries in major European countries, labour productivity growth is found to be a key driver of both distributive components, while a systematic negative relation between wages and profits reflects the importance of the capital-labour conflict. Product innovation is positively associated with both profit and wage growth; conversely, new processes lead to a reduction of wages. Offshoring is a clear driver of profits and a tool for reducing labour compensation. Finally, union density is positively associated with wage dynamics. Profits are clearly benefitting more than wages from the different trajectories of technological change and international production (Coveri and Pianta 2019).

Disparities among wages have also significantly increased. Across educational levels and skills, wages tend to be higher and grow faster for workers with higher education, higher skills or using computers at work (Acemoglu, 2002). Across industries we generally find that high innovation manufacturing and service industries have higher wage levels and faster wage increases, contributing to wage polarisation (Galbraith, 2012; Coveri and Pianta 2019).

However, the relationship between innovation and wages may also run in the opposite direction; low wages, precarious work and high labour market flexibility can eliminate a major incentive for introducing innovation in firms, resulting in worse technological performances (Kleinknecht et al. 2014; Cetrulo et al. 2019).

Labour market institutions also play a major role in the rise of wage disparities. The last OECD report on inequality (OECD, 2015) emphasises the responsibility of weaker labour market institutions in the rise of wage inequality. The report acknowledges that "declining union coverage had a disequalising effect on the wage distribution" and that "high union density and bargaining coverage, and the centralisation/co-ordination of wage bargaining tend to go hand in hand with lower overall wage inequality in both OECD countries and emerging economies" (OECD, 2015, p. 42). The problem of non-standard and precarious jobs is pointed out: "a non-standard job typically pays less than traditional permanent work (…). These earning gaps are especially wide among low-skill, low-paid workers: non-standard workers in the bottom 40% of earners typically suffer wage penalties of 20% (…). Non-standard workers also face higher levels of insecurity in terms of the probability of job loss and unemployment and, in the case of temporary workers, report significantly higher job strain" (ibid. p. 31). The OECD now advocates a minimum wage that "can help supporting low-wage workers and low-income families while avoiding significant job losses (ibid., p. 42).

A similar argument has been made by the IMF in a study (Dabla-Norris et al., 2015) showing that a decline in organised labour institutions is associated to higher inequality measured by Gini coefficients, "likely reflecting the fact that labor market flexibility benefits the rich and reduces the bargaining power of lower-income workers". Additional evidence shows that "more lax hiring and firing regulations, lower minimum wages relative to the median wage, and less prevalent collective bargaining and trade unions are associated to higher market inequality" (Dabla-Norris et al., 2015, p.26).

The above evidence suggests the need for policies addressing the distribution of the productivity gains resulting from technological change. Over the past decades, innovation has mainly benefited capital in the form of higher profits, top earnings and financial rents in a context of increasing pressure on firms from investors demanding high financial returns. Conversely, technological change has often hit workers with job losses associated to labour saving new processes, with new forms of low wage precarious work, with stagnant real wages. Technology is one of the engines of income inequality that has now reached record levels in many advanced and emerging countries. Such disparities are

not only a problem of social justice, they also undermine the possibility of growth and efficiency – as argued also by the OECD: "when income inequality rises, economic growth falls" (OECD, 2015, p.60). New policies are therefore required for shaping technological change in the interest of society; for reducing its negative employment effects; for making sure that the gains from innovation and productivity go to labour in the forms of higher wages, lower working hours and improved working conditions.

References

Acemoglu, D. (2002) Technical change, inequality and the labor market, Journal of Economic Literature, 40,1, 7-72

Acemoglu, D. and Restrepo, P. (2017) *Robots and Jobs: Evidence from US labor markets*. NBER Working Paper No. w23285.

Autor, D., Katz, L. and Krueger, A. (1998) Computing inequality: have computers changed the labor market? Quarterly Journal of Economics, 113, 1169-1214.

Autor, D., Dorn, D., Katz, L., Patterson, C., Van Reenen, J. (2017) The fall of the labor share and the rise of superstar firms, IZA Institute of Labour Economics Discussion Paper No. 10756.

Berman, E., Bound, J. and Machin, S. (1998) Implications of skill biased technological change: international evidence. Quarterly Journal of Economics, 113, 1245-79

Bogliacino, F., and Pianta, M. (2010) Innovation and employment: a reinvestigation using revised Pavitt classes, Research Policy, 39: 799-809.

Bogliacino, F., Perani, G., Pianta, M., Supino, S. (2011) Innovation and Development. The Evidence from Innovation Surveys, Latin American Business Review 13: 1-44

Bogliacino, F., Lucchese, M. and Pianta, M. (2013) Job creation in business services: Innovation, demand, and polarisation. *Structural Change and Economic Dynamics*, Elsevier, 25(C), pp. 95-109.

Braverman, H. 1974. Labour and Monopoly Capital, New York, Monthly Review Press

Bramucci, A., Cirillo, V., Evangelista, R., Guarascio, D. (2017) Offshoring, industry heterogeneity and employment. *Structural Change and Economic Dynamics*, https://doi.org/10.1016/j.strueco.2017.09.002.

Brynjolfsson, E., and A. McAfee (2014) The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. W. W. Norton & Company, Inc., New York.

Card, D. and Mas, A. (2016) Introduction: The Labor Market in the Aftermath of the Great Recession. *Journal of Labor Economics*, 2016, vol. 34, Issue S1, pp. S1-S6.

Cetrulo, A., Cirillo, V., Guarascio, D. (2019) Weaker jobs, weaker innovation. Exploring the effects of temporary employment on new products, Applied Economics, https://doi.org/10.1080/00036846.2019.1619015

Chui, M., Manyika, J. (2015) Competition at the digital edge: 'Hyperscale' business, McKinsey Quarterly, March 2015.

Cirillo, V. (2016) Technology, employment and skills, Economics of Innovation and New Technologies, DOI: 10.1080/10438599.2017.1258765.

Cirillo, V., Pianta, M., Nascia, L. (2018) Technology and occupations in the Great Recession. Sustainability, 10 (2): 463.

Cirillo, V., Molero Zayas, J. (2019) Digitalizing industry? Labor, technology and work organization: an introduction to the Forum, Journal of Industrial and Business Economics, https://doi.org/10.1007/s40812-019-00126-w

Coveri, A., Pianta, M. (2019) Technology and income distribution, Cambridge Journal of Economics (forth.).

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, Washington D.C., IMF.

Dosi, G. 1982. “Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change”. *Research Policy* 11 (3): 147-162.
Dosi, G., Freeman, C., Nelson, R., Silverberg G. and Soete L. (eds) (1988) Technical Change and Economic Theory, London, Pinter
Eurofound (2013) Employment polarisation and job quality in the crisis: European Jobs Monitor 2013. Eurofound, Dublin.
Franzini, M., Pianta, M. (2016) *Explaining inequality*, London, Routledge.
Freeman, C. and Louçã, F. (2001) As time goes by. From the industrial revolution to the information revolution. Oxford, Oxford University Press
Freeman, C. and Soete, L. (1994) Work for all or mass unemployment?, London, Pinter
Freeman, C. and Soete, L. (eds) 1987. Technical Change and Full Employment, Oxford, Basil Blackwell
Freeman, C., Clark, J. and Soete, L. (1982) Unemployment and Technical Innovation, London, Pinter
Frey, C., Osborne, M., (2017). The future of employment: How susceptible are jobs to computerisation?. Technological Forecasting and Social Change, 114, pp. 254-280.
Galbraith, J. (2012) Inequality and instability. Oxford, Oxford University Press.
Goldin, C. and L. F. Katz. 2008. “The Race between Education and Technology: The Evolution of U.S. Educational Wage Differentials, 1890 to 2005”. *NBER Working Papers 12984.*
Goos, M. and Manning, A. (2007) Lousy and Lovely Jobs: The Rising Polarisation of Work in Britain. *The Review of Economics and Statistics*, MIT Press, vol. 89(1), pp. 118-133, February.
Goos, M., Manning, A. and Salomons, A. (2014) Explaining Job Polarization: Routine-Biased Technological Change and Offshoring. *American Economic Review*, 104(8): pp. 2509-26.
Guarascio, D., Sacchi, S. (2018) Digital platforms in Italy; an analysis of economic and employment trends, INAPP Policy Brief, 8, June 2018, Rome.
Heertje, A. (1973) Economics and technical change. London. Weidenfeld and Nicolson
Kleinknecht, A., van Schaik, F. N., Zhou, H. (2014): “Is flexible labour good for innovation? Evidence from firm-level data,” Cambridge Journal of Economics, 38, 1207–1219.
ILO (International Labour Office) (2015) World Employment Social Outlook. The changing nature of jobs. Geneva, ILO.
Leontief, W. and Duchin, F. (1986) The Future Impact of Automation on Workers. Oxford, Oxford University Press
Lucchese, M. and Pianta, M. (2012) Innovation and Employment in Economic Cycles. *Comparative Economic Studies*, Palgrave Macmillan, vol. 54, 2, pp. 341-359.
Marx, K. 1961. *Capital*. Moscow, Foreign Languages Publishing House, first edn. 1867.
Mastrostefano, V. and M. Pianta. 2009. Technology and jobs. *Economics of Innovation and New Technologies* 18 (7-8): 729-742.
Mensch, G. 1979: *Stalemate in technology*. Ballinger: Cambridge.
Nelson, R. and Winter, S. (1982), An Evolutionary Theory of Economic Change, Cambridge (Mass.), The Belknap Press of Harvard University Press
Noble, D. (1984) Forces of Production: A Social History of Industrial Automation, New York, Knopf.
OECD (2015) In it together. Why Less Inequality Benefits All. Paris, OECD.
OECD (2018) Oslo Manual 2018. Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, Paris, OECD.
Pasinetti, L. (1981) Structural Change and Economic Growth, Cambridge, Cambridge University Press
Pavitt K. (1984): "Patterns of technical change: towards a taxonomy and a theory", Research Policy, 13, 343-74.
Perez, C. (1983), Structural change and the assimilation of new technologies in the economic and social systems, Futures, 15, 5, 357-75
Perez, C. (2002): "Technological revolutions and financial capital", Cheltenham, Edward Elgar.

Pianta (2000) The employment impact of product and process innovation, in Vivarelli and Pianta (eds)
Pianta, M. (2001) Innovation, Demand and Employment. In: Petit, P, Soete, L. (eds.) *Technology and the future of European Employment*. Cheltenham, Edward Elgar, 142-165.
Pianta, M. (2005) Innovation and Employment. In: Fagerberg, J, Mowery, D, Nelson, R. (eds.). *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.
Pianta, M. (2018) Technology and employment. Twelve stylized facts for the digital age. Indian Journal of Labour Economics, 61, 2, 2018: 189-225.
Pianta, M. and Vivarelli, M. (2000). Conclusions: are employment friendly policies possible? In Vivarelli and Pianta (2000).
Pianta, M., Tancioni M. (2008) Innovations, wages and profits, Journal of Post Keynesian Economics, 31, 1, 101-123.
Piketty, T. (2013) Le capital au XXI siècle, Paris, Seuil. English translation (2014) Capital in the twenty-first century. Cambridge (Mass.) Harvard University Press.
Polanyi, K. (2001) The Great Transformation: The Political and Economic Origins of Our Time, Boston, Beacon Press (original edn 1944).
Reljic, J., Evangelista, R., Pianta, M. (2019) Digital technologies, employment and skills, Industrial and Corporate Change (forth.)
Ricardo, D. (1951) Principles of Political Economy and Taxation, in Sraffa, P. (ed.), The Works and Correspondence of David Ricardo, vol. I, Cambridge, Cambridge University Press (third edn, original edn 1821).
Schumpeter, J.A. (1934) Theory of Economic Development, Cambridge (Mass.), Harvard University Press (1st edn 1911)
Shaiken, H. (1984) Work transformed. Automation and labor in the computer age. New York, Holt, Rinehart and Winston
Sylos Labini, P. (1969). Oligopoly and Technical Progress, Cambridge (Mass.), Harvard University Press, first edn 1956
Vivarelli, M. (1995). The Economics of Technology and Employment: Theory and Empirical Evidence, Aldershot, Elgar
Vivarelli, M. (2014), Innovation, Employment, and Skills in Advanced and Developing Countries: A Survey of the Economic Literature, Journal of Economic Issues, 48, 123-154.
Vivarelli, M. and Pianta, M. (eds) (2000), The Employment Impact of Innovation: Evidence and Policy, London, Routledge.
Zuboff, S. (2019) The age of surveillance capitalism, London, Profile Books.