THE LUDDITE LEGACY: WHY THE INITIAL DIFFUSION OF TECHNOLOGIES DOES NOT PREDICT THE FUTURE OF WORK

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This paper examines the relationship between the fears of technological unemployment that have been generated by Schumpeterian 'creative destruction' in the early years of each technological revolution in the industrial era, and the reality of how each transformation has affected jobs, income and inequality. It synthesises and critically analyses the growing body of academic work on the future of work, bringing a neo-Schumpeterian perspective – one that emphasises the interaction between technology, policy, politics, and society – to that scholarship to reveal underlying misassumptions and to understand how and in what ways synergistic transformations have led to the creation of new jobs across the entire socio-economic space. While not denying that there is cause for concern, this paper takes issue with assumptions of predictability. This may seem paradoxical for a study that purports to learn from the past. However, building on the work of the BEYOND4.0 Background Paper (D7.1; Perez and Murray Leach 2021), it argues that current thinking – as at similar historical moments – is mired in the logic and experience of the previous technological paradigm. Too often, it is also limited in scope, analysing standard economic metrics and being purely techno-economic in focus, ignoring the socio-political factors that influence the outcomes. This paper analyses the historical role played in previous revolutions by changes in lifestyles and government policy. It is shown that they have provided directionality for innovation and investment, resulting in the creation of new jobs replacing the initial losses and in a general synergistic path for the economy in what have been called the 'golden ages'.

Keywords: technological revolutions; industrial revolutions; technological unemployment; transformation; economic growth; economic development; technological determinism; installation period; deployment period; paradigms; directionality; lifestyles; Luddite; Luddism; future of work

BEYOND4.0 partners to this deliverable

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Executive Summary

This is the second of three papers that provide a historical perspective on technological transitions for the BEYOND4.0 project. The main premise of BEYOND4.0 is that technology is not deterministic but is socially negotiated by key actors, and that this understanding opens up the possibility that the EU can assist in the creation of an inclusive economy that provides decent work and lives for EU citizens. The objective of the historical work package (WP7) is to provide insight into the process(es) of technological transformation at a societal level. While the first of the three WP7 papers interrogates the theoretical basis underpinning the very concept of BEYOND4.0, and the third focuses on the role that the state has played in the flourishing of each revolution, this Working Paper concentrates on a core topic of investigation for BEYOND4.0: the impact of new technologies on the future of work. Its object is to analyse the effects of previous technological revolutions on employment and wages in order to inform policy prescription in the present.

Currently, there is considerable debate in both academic and policy circles on the impact of so-called 'Industrie 4.0' technologies on the future of work and the labour market. Rather than the inclusive future that the H2020 Work Programme (2018-2020) aims to deliver, the dominant analysis of the data predicts a different world. It sees the intensification of technological unemployment due to automation, robotics and artificial intelligence (AI), and a 'hollowed out' job market, with the jobs that do remain being skewed towards either end of the skills, wage and productivity scales (Frey and Osborne 2013; Ford 2015; Haldane 2015; Acemoglu and Restrepo 2018). Yet as Frey (2019) and many others have noted, these fears are not unprecedented. The advent of industrialisation was accompanied by not only the protests of the Luddites but by a public discourse of concern about the effects of new technology on the future of work, and this discourse has re-emerged with every technological shift. This Working Paper is particularly interested in why and in what ways the future of employment has been misjudged at times of transformation in the past – during the moments in history that are comparable to the period in which we find ourselves now.

In order to do so, the paper integrates the findings of two research tasks. The first was to study the fears and the numerical reality of technological deskilling and unemployment in each technological transformation, from the start of the industrial era through the recent information technology shift. The second aimed to assess the long-term impact of systemic change on job creation and income (in)equality over the same period; in other words, to provide the more positive 'view from the other side' of each transformation. The paper thus synthesises the literature on technological unemployment and job creation from the start of the Industrial Revolution to the present, and analyses and critiques the available historical data on employment, wages, productivity and (in)equality from the same period.

It is true that the early decades of the five revolutions identified in the Beyond 4.0 Background Paper (D7.1; Perez and Murray Leach 2021) have seen an ominous period of 'creative destruction' when the new technologies destroy skills, jobs, companies, and even whole industries and regions. The paper maps out the fears of new technologies that have accompanied that destruction. It

critiques the claim that these fears have been primarily focused on the new technologies only in epochs when those technologies have been 'labour replacing' (Frey 2019), and rather locates the 'discursive continuity' of the Luddites (Binfield 2004) in the 'repertoires of contention' (Tilly 1993) that have arisen in protest at the hardships and increases in inequality that have accompanied every technological revolution to date.

It is also the case that each transition has seen new jobs created. Rather than take a narrow focus on the productivity of new industries, or skills training in order to 'counter' the negative effects of technological change, as does much of the existing literature, this paper takes more positive a neo-Schumpeterian perspective. It endeavours to understand the breadth of changes that have historically occurred at the systemic level, noting how public policy has intervened to shape the context and the direction of the new technologies, in order for jobs to be created across the socio-economic spectrum. It also points out the limitations of the historical data on which most long-term analyses are made: from errors, to omissions, to issues of perspective.

Finding such data limited in scope, it analyses two aspects of the complex interactions between the techno-economic and socio-political spheres that the historical record suggests are vital in this process, but which are typically overlooked. The first is 'directionality': the way in which governments have 'tilted the playing field' in previous transitions by creating market conditions that favour particular synergistic directions for innovation. The second is the crucial role that a shift in lifestyles plays. The research indicates that while the new tech industries see the highest productivity, it has been the development of industries catering to these new ways of living that created the most employment.

The paper thus contends that it is erroneous to link rising inequality in the present to the rise in jobs in the service industry.. According to the historical record, wage levels have not only been set by type of jobs or level of skills. Like price levels, they are socio-politically influenced. Not only has this occurred in response to political pressure brought about by the repertoires of contention, from machine-breaking to union negotiating, but has also been politically influenced and enabled by the overall wealth created by the greater productivity of the new technologies and by the need for sufficient demand provided by the new ways of living, and unleashed by the appropriate policies.

Building on the argument put forward in the Background Paper (D7.1; Perez and Murray Leach 2021), and on the work of other BEYOND4.0 teams that challenges deterministic thinking, this paper contends that in many cases, the predictions being made now are as unreliable as the doom-mongering of the past. Such projections rest upon (typically unrecognised) techno-deterministic assumptions about the inevitability of technological trends, and therefore the solutions offered tend to be trapped in the common-sense logic of the previous revolution and in the initial 'creative destruction' process of the new one.. It follows that the policy suggestions that result from those analyses are likely to be both wrong and obsolete. This Working Paper thus aims to contribute to a more realistic approach to the analysis of labour market futures and to the design of effective policies toward the best possible outcomes.

1. Introduction

What wonderful accessions have thus been made, and are still making, to the physical power of mankind; how much better fed, clothed, lodged and, in all outward respects, accommodated men now are, or might be, by a given quantity of labour, is a grateful reflection which forces itself on everyone. What changes, too, this addition of power is introducing into the Social System; how wealth has more and more increased, and at the same time gathered itself more and more into masses, strangely altering the old relations, and increasing the distance between the rich and the poor, will be a question for Political Economists, and a much more complex and important one than any they have yet engaged with.

(Carlyle 1829)

As the impact of information technologies has propagated across our socio-economic landscape, **fears about the future of work have been growing**. Rather than the inclusive future that the H2020 Work Programme (2018-2020) aims to deliver, these fears predict a different world: technological unemployment due to automation, robotics and artificial intelligence (AI), and a job market that is 'hollowed out', leaving the jobs that do remain skewed towards either end of the skills, wage and productivity scales (Frey and Osborne 2013; Ford 2015; Haldane 2015; Acemoglu and Restrepo 2018).

Fears centred on the power of new technology to replace jobs are not unprecedented. The advent of industrialisation in Britain was accompanied by not only the protests of the Luddites but by a public discourse of concern voiced by politicians, intellectuals and social campaigners. And, indeed, these were not empty fears. The early decades of each of the five technological revolutions since the industrial breakthrough in England, have seen an ominous period of radical change when the **new technologies destroy skills, jobs, companies, and even whole industries and regions**. It is what Schumpeter called 'creative destruction' as the way innovation behaves in market economies. Each such period has generated a new but familiar set of fears in which the near future seems both predictable and of concern. **Yet it is also the case that each transition has seen new jobs created, some related to the new technologies themselves, others to the new lifestyles and consumption patterns they later enable**. The jobs that countered those fears would have been unimaginable years before.

Since the irruption of the information revolution **in the last decades of the 20th century, analyses of the future of work have multiplied**. The fears around technological unemployment have become commonplace – at least in the academic fields concerned with economics, innovation and technological change, in policymaking around employment and innovation, and in the business and popular press.

As discussed in Perez and Murray Leach (2021), the background historical paper for the BEYOND4.0 project, when it comes to the consequences of information technology on future economic growth and productivity, there are diverging positions. The techno-pessimists, such as Gordon (2012) and Cowen (2011), believe that the 'low-hanging fruit' has been picked and that the growth of the past 150 years is an exceptional event in history. More common, however, are the analyses that, **while being optimistic about economic growth and general prosperity, are much less so about the future of employment and wages**. They see artificial intelligence, robotics and other advanced digital technologies as incredibly powerful and promising, but also inevitably job destroying (Brynjolfsson

and McAfee 2014; Frey and Osborne 2013). They all express concerns about rising inequality, but the policy actions they propose tend to be 'band aid' solutions, rather than recognising the systemic change that is now needed to be effective..

While we share many of their concerns about the current labour problems – such as stagnating wages, precarious jobs, skill destruction, the gig-economy, and zero-hours contracts – we draw different lessons from our research into the history of technological revolutions. On that basis, we see their analyses as too limited in focus. Our goal with this paper is to employ a neo-Schumpeterian framework to broaden the scope of the debate on the future of work. We aim to shine a light on why the future of employment has repeatedly been misjudged in the early decades of each technological revolution. We will examine the historical record to illustrate how the transformations that have occurred in each previous instance have later led to 'golden ages' characterised by the creation of new jobs and reversals of inequality for successive layers of the population.

In particular, we wish to highlight the breadth of the changes that the historical record suggests must occur at the systemic level for the creation, not only of jobs, but of jobs that meet the EU's 'quality of employment' measures or the comparable 'decent work' aim adopted by the International Labour Organization in 1999 and added to the UN Millennium Development Goals in 2007 (Burchell et al. 2014; Brill 2021).[1] As set out in Perez and Murray Leach (2021), while the neo-Schumpeterian approach to understanding the functioning of the economy adopts the core Schumpeterian belief of innovation as the source of dynamism and growth, it does not see the market as the sole determinant of economic behaviour, nor technology as an autonomous, unstoppable force. It is an evolutionary approach, which views the economy as a complex system and technology as ultimately being socially shaped. It understands the processes of technical change as the result of complex interactions between the techno-economic and the socio-political spheres and their mutual shaping.

In this paper, we analyse previous transitions focusing particularly on two aspects of these interrelations that our research suggests have led to the creation of new jobs and the reduction or even reversal of inequalities. The first is 'directionality', referring to the way in which governments have 'tilted the playing field' by creating market conditions that favour particular synergistic directions, among those that the new technologies have already indicated in action. Both born from such a direction and innovating along it, we identify the shift in lifestyles as a second aspect of the change process, crucial in new job creation. While the regulatory role of the state is often mentioned in prescriptions for the future of work, and patterns of consumption are touched upon, they are typically dealt with as sidenotes to the focus on labour. Here, we aim to centre the roles played in the past by a change in government policies and the creation of a new aspirational lifestyle/s.

Finding this systemic approach lacking in the current literature on the future of work, our approach includes a critical appraisal of that literature. Furthermore, we hold to the growing consensus which argues that the upswings and downswings of macroeconomic aggregate data can conceal more

[1] "Decent work is the converging focus of all [of the ILO's] four strategic objectives: the promotion of rights at work; employment; social protection; and social dialogue." Juan Somavia, Director General of the ILO, in 1999, cited in Brill (2021, p.13). Gerry Rodgers, a policy researcher at the ILO, added: "Promoting employment without considering the quality and content of those jobs is no recipe for progress. Promoting rights at work without worrying about whether or not there is work for those who want it is equally fruitless." (ibid).

than they reveal – or, at best, tell only a partial story (Waring 1988; Freeman and Louçã 2001; Raworth 2017; Mazzucato 2018). Therefore, this paper takes a critical perspective toward the burgeoning historical datasets of labour economics (notably of employment, occupations, labour productivity and inequality), while recognising that there are valid and useful inferences that can be drawn from them.

However, **building on the argument put forward in Perez and Murray Leach (2021), our contention is that in many cases, the predictions being made now are as unreliable as the doom-mongering of the past**. This is for two primary reasons: because their projections rest upon (typically unrecognised) techno-deterministic assumptions about the inevitability of technological trends; and because the solutions offered are usually trapped in the trends of the immediate past. It follows that the policy suggestions that result from those analyses are likely to be both wrong and obsolete. **We thus hope to contribute to a more realistic approach to the analysis of labour market futures and to the design of effective policies toward the best possible outcomes.**

The paper is structured as follows: Section **one** briefly **revisits the definitions and rationale of our approach** to the study of technological change as laid out in the BEYOND4.0 background paper (Perez and Murray Leach 2021).

Sections **two** and **three synthesise the empirical evidence available from the literature on technological unemployment**: first on the fears and then on the reality of previous technological revolutions, in terms of numbers and in their relationship to inequality and productivity. In our analysis of these sources in this paper, we refer in particular to the recent work of Frey (2019), whose book *The Technology Trap* covers similar ground and is a rich source of both the available data and academic literature on the topic.[2] **We critically discuss both the interpretations and the findings and limitations of that data** and review to what extent it confirms or contradicts the working hypothesis used in Tasks 7.2 of BEYOND4.0: that the ill effects of technological transitions were especially pronounced in the mid-nineteenth and late nineteenth century, and the 1930s, the transitional moments identified by the five surges model. Note that our focus throughout the paper is on the core countries that have led each historical transition: Britain, Germany and the United States.[3]

Section **four** looks at the role of directionality and of lifestyles in the creation of new jobs with each revolution. It puts forward the theory of directionality touched upon in Perez and Murray Leach (2021), and examines the different directions that have led to job creation in each of the

[2] Published a year after the Beyond 4.0 proposal was submitted, The Technology Trap (Frey 2019), contains an impressive collection of descriptive data about the fears and realities of technological unemployment over the past 250 years, alongside Frey's analysis of the impact of technological change on society and a chapter of prescriptions for the future. While the book is marketed as a work of popular economics, it is also a significant repository of academic literature on the topic. Given that Frey is a senior researcher on our sister Horizon 2020 project, Technequality, it would be disingenuous of us not to acknowledge that it covers much of the same ground as the research that we undertook for Tasks 7.2 and 7.3, and in far greater detail than could be attempted for a single paper. We shall address his analysis, in sections two and three, in particular. However, we should make clear that this paper is not an attempt to refute his work, which we find valuable. Rather, as it covers the literature extensively and employs a version of the dominant analysis in the debate, it is a useful device through which to explore some of the limitations of such literature.

[3] For further discussion on the rationale and limitations of this focus, see Perez (2002) Ch. 6.

revolutionary surges. It identifies the successive lifestyles and the types of jobs created to cater to their demands.

Section five looks at the interplay of directionality and lifestyles with productivity, employment and inequality. It highlights the role of increasing productivity in making progress possible but notes how each revolution begins by increasing inequality and only delivers social improvement once the new technological potential has spread across the economy and the government has provided the appropriate social policies.

We conclude by questioning both technological determinism about jobs and the inevitable continuation of the current levels of inequality by acknowledging the regularities in the historical pattern, without denying the uniqueness of this revolution, as that of every previous one.

2. Technological Revolutions Revisited

Before delving further into specifics around employment, **we restate in brief the neo-Schumpeterian five surges model of technological change** that we are using for our analysis, as defined in the historical background paper for BEYOND4.0 (Perez and Murray Leach 2021), and we highlight where it differs from other approaches to the future of work. BEYOND4.0 is named after the term Industry 4.0, used by Klaus Schwab and the World Economic Forum to imply that we are currently in the Fourth Technological Revolution, based on artificial intelligence (AI), robotics and biotechnology (Schwab 2016). Although that is currently the dominant framework for understanding the present transition, **we argue in the background paper that the five surges model imparts a necessary – and complementary – breadth and depth, both as an empirical observation of historical events and as a heuristic device**. Of particular relevance for this paper is the emphasis on the roles of different elements in driving the transformations – from radical changes in technology to lifestyles to policy choices – and the different phases of diffusion of each revolution. Such a sequence recognises the vast range of viable areas for innovation, allowing us to identify the technological determinism underlying many of the current analyses of expected trends. We consider it **vital for identifying the many opportunities for the social shaping of technology for the benefit of the majority**.

It is increasingly recognised not only that economic growth is driven by innovation but also that innovation clusters in successive technological revolutions (Landes 1969; C. Freeman and Louçã 2001; Perez 2002; Schwab 2016). As we discussed in Perez and Murray Leach (2021), **economists, historians and those in related disciplines have differed in their periodisation of these techno-economic transformations**. While the precise dates vary depending on the scholar, the majority of academic analyses and popular renditions that refer to qualitative and/or quantitative data from the past in order to forecast the future-of-work follow a three revolutions model: the industrial revolution, the second industrial revolution of electricity and the internal combustion engine, and the digital revolution (Frey 2019). This holds even in revisionist work, such as that which highlights that the shift towards industry and services in Britain began much earlier than the symbolic 'big bang' of the spinning jenny in the 1760s. A notable exception here is the work of Brynjolfsson and McAfee (2014), which divides the past into only two machine ages: the industrial one from the 18th to the 20th century, mechanising manual work, and the digital one beginning sometime around the turn of the 21st century, mechanising mental work.

Scholars also differ as to their take on the composition and causalities of each revolution. The most directly technological interpretations refer primarily to the major inventions of each period (the Rocket steam engine, electricity, Ford's Model-T, computers), while those who focus on the economic impact look for empirical evidence in the upswings and downswings (cycles and waves) of growth data. **The neo-Schumpeterian perspective takes the complex systems-oriented approach**, building on the work of innovation scholars and evolutionary economists (Nelson and Winter 1982; Dosi et al. 1988). Technology, in this definition, includes the tools, knowledge and experience used in the design, production and distribution of goods and services, including both organizational and technical aspects. **Every technological revolution is comprised of interrelated constellations of technology systems which evolve around a powerful and dynamic cluster of radical innovations**

which have multiple sources across different sectors. For each one, we can identify new low-cost inputs (sources of energy or materials), new infrastructures, new products and processes, and new forms of organisation. These can be seen as generating a **great surge of development,** bringing major structural changes in production, finance, distribution, communication and consumption. This process evolves from niche beginnings in restricted sectors and, historically, geographic regions; as it takes hold, it then diffuses out from the niche to the mainstream, and from the core country/ies towards further and further peripheries (Perez 2002).

When the historical record is viewed with this lens, **five revolutions are recognised** (see Table 1).

Table 1. Five successive technological revolutions

Technological revolution	*Popular name for the period*	*Core country or countries*	*Big-bang initiating the revolution*	*Year (from)*
FIRST	The 'Industrial Revolution'	Britain	Arkwright's mill opens in Cromford	1771
SECOND	Age of Steam and Railways	Britain (spreading to the Continent and USA)	Test of the 'Rocket' steam engine for the Liverpool-Manchester railway	1829
THIRD	Age of Steel, Electricity and Heavy Engineering	USA and Germany forging ahead and overtaking Britain	The Carnegie Bessemer steel plant opens in Pittsburgh, Pennsylvania	1875
FOURTH	Age of Oil, the Automobile and Mass Production	USA (with Germany at first vying for world leadership), later spreading to Europe	First Model-T comes out of the Ford plant in Detroit, Michigan	1908
FIFTH	Age of Information and Telecommunications	USA (spreading to Europe and Asia)	The Intel microprocessor is announced in Santa Clara, California	1971

Source: Based on Perez (2002), Table 2.1. p. 11. For a more detailed table of industries, infrastructures and paradigms, please see the BEYOND4.0 Historical Background Paper (Perez and Murray Leach 2021, Table 2, pp.23-26).

What is crucial to understand when attempting to predict the future of work – and, to an extent, this holds whether four or five revolutions are recognised – is that **each revolution has a double nature. The most recognisable feature is the set of new technologies. However, it is the other aspect that has the most pervasive impact: the emergence of a new 'common sense' best practice (a *techno-economic paradigm*) for innovation, investment and consumption**, capable of transforming every other industry and activity and providing a quantum leap in productivity across the whole economy. The replacement process, rightly referred to by Schumpeter (1942) as 'creative destruction' is painful both for the workers who may lose skills and jobs and for the managers who

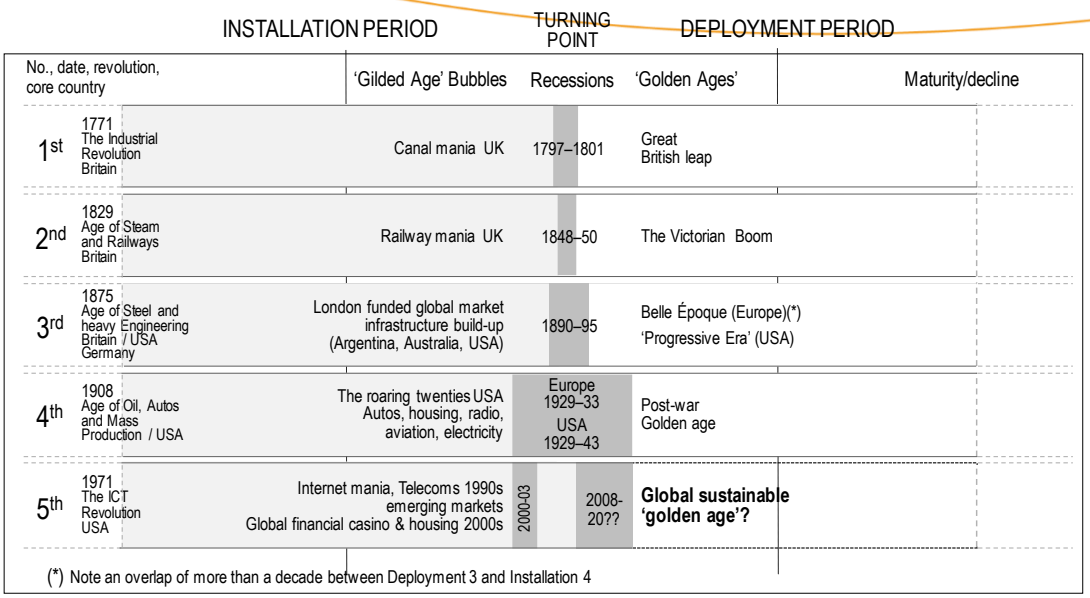
must radically change what they considered the most effective and profitable practice. **It is the extrapolation of this destructive potential, without taking into account the possibility of social shaping, that causes the greatest fears and ominous predictions about the future of work**, as we discuss in section two.

A striking example of the problem of perception – the magpie-like appeal of the new technologies, shining so brightly that they dazzle and blind – is revealed by still fairly recent revisions to both narrative and numerical assessments of the eighteenth and nineteenth century, as discussed in section three, which find that **the service sector 'has received far less attention' from scholars than the new technology manufacturing industries, despite being 'the dominant sector within the [British] economy' since the mid-nineteenth century** (Cain and Hopkins 1986; Broadberry et al. 2015). These empirically-backed revisions are coming from the most prolific and experienced scholars in the field and can be seen in the direction that micro-studies of the period are taking (Shaw-Taylor et al. 2019). **Yet, for many years, the history of economic growth in both the nineteenth and twentieth century was written as a history of manufacturing. It is the inputs, outputs and firms of that sector that underpin the discipline of economics and the majority of its concepts**. And in both popular and academic writing about the past in the future-of-work area, the emphasis remains on the growth, and loss of the manufacturing sector – for employment, wages and productivity (Broadberry et al. 2015).

That the potential of technology takes time to have an impact on the economy is not a unique takeaway from the five surges model. Yet while there is a general acceptance in the future of work discourse that productivity benefits require a certain period of time to bear fruit, the three-revolutions model does not identify any particular pattern of diffusion and mainly sees the market as the mechanism responding to the potential of the technologies. **Critical for the arguments of this paper is the neo-Schumpeterian recognition of a distinct pattern in the process of propagation of each revolution or what Perez (2002) calls a 'great surge of development'**. Each of these surges goes through two different periods, split by one or more major economic crashes, which follow financial bubbles (see Fig 2). The *installation period* is the time of 'creative destruction' (Schumpeter 1942), in which the new technologies emerge in a competitive experiment led by financial capital. It is during these years that one would expect to see the replacement or displacement of established industries, the destruction of jobs and skills and the upheaval of previously dominant sectors, regions and countries. It is also the time that fears around new technologies, we hypothesise, are most likely to surface. Figure 1 presents the pattern as it has occurred historically.

Figure 1

The Neo-Schumpeterian pattern from the historical record of technological revolutions



Source: Perez 2016, Ch 11. p. 195.

The recessions that follow the bubble(s) and put an end to this period of intense competition and financial speculation reveal all the inequalities that have resulted, thus serving as fertile ground for intensifying the fears about the future. However, by this moment in the diffusion process – the *turning point* – the installed potential of the revolution is ready in the wings to transform the rest of the economy. These are the golden ages that have lifted successive layers of the population to better lives. But this has only happened, historically, if and when the adequate context is created by the government to facilitate its unleashing in a synergistic direction. **While the notion of 'creative destruction' has become so well-known as to become a cliché, there is far less understanding of this second and, arguably, far more important phase of the cycle because it is when society – through the intervention of the State – shapes technology.** We discuss this in more detail in section four.

Once the potential of the revolution is exhausted for increasing productivity, markets and new products, the paradigm reaches *maturity*. By then, the gestation of the next revolution is taking place in the economic space. What hinders this transition, right throughout the next installation period and into the subsequent turning point – is the resistance produced by the now deeply ingrained 'best practice' of the previous paradigm. The old processes and institutions that produced growth and welfare under the prevailing conditions become obsolete and no longer suited to the new context. **We argue that the majority of policy recommendations to deal with the changing face of jobs and inequality are limited by the inertial force of that perspective**. In section three, we shall look at the realities of job creation once this inertia has been overcome in the previous revolutions; but first, we turn to the fears that initially limit each transition to the new paradigm.

3. Fears of Technological Change

… all the past rules of forecasting economic and industrial trends are out the window […] the day is coming when 2% of our population […] will be able to produce all the goods and food that the other 98% can possibly consume, [and] that day will arrive no later than 25 years from now, and […] more likely it will arrive in about 10 years.

Dr Richard Bellman, RAND Corporation employee and inventor of dynamic programming, paraphrased in the 1967 Life Magazine investigation into the future-of-work, 'The Emptiness of Too Much Leisure'

3.1 Luddism and fear in popular discourse

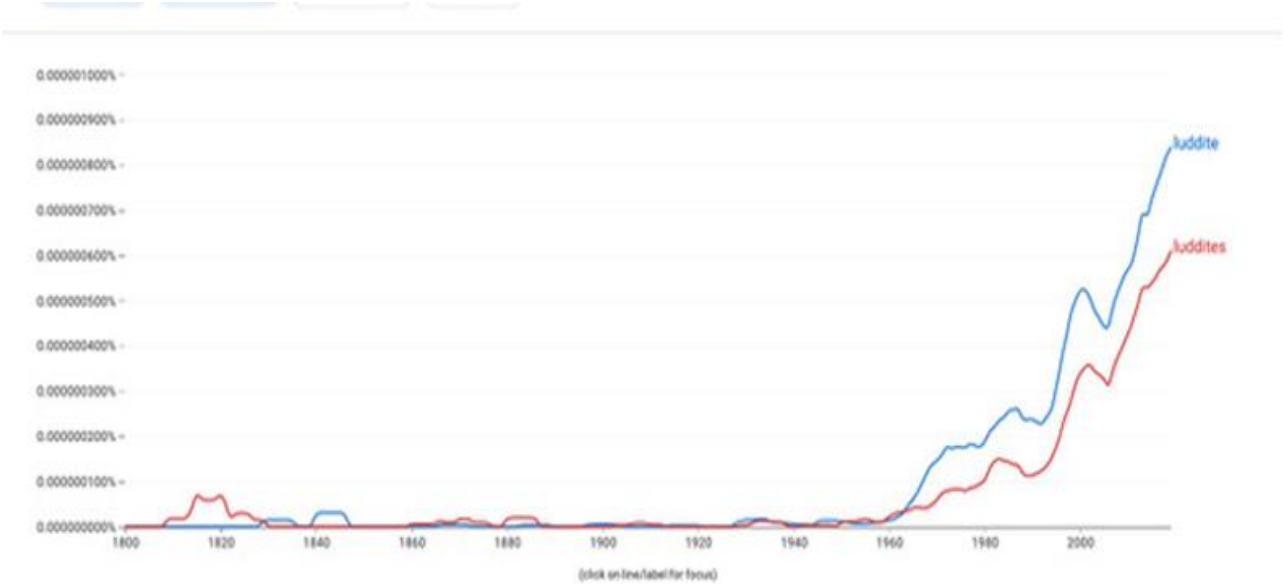
The title of this paper refers to the Luddite rebellions of the 1811-1816: specifically, to the destruction of worker-replacing machinery that occurred as an element of those rebellions; the commonly-held interpretation of that destruction as an indication of distrust of new technologies and the fear that the technologies will replace human jobs; and the fact that such fears have resurfaced with every technological revolution. As we shall discuss, **that popular interpretation of the original protests is inaccurate** (Binfield 2004; Jones 2006). This chapter examines the meaning and impact of these recurrent fears by employing the neo-Schumpeterian perspective outlined in section one to carry out a critical literature review of key contributions to the history of this aspect of technological change, and challenge extrapolations that have been made by comparing past fears to those of the present.

As Figure 2 demonstrates, the use of the NGRAM method to obtain **a snapshot of popular discourse indicates a revival of the 'discursive continuity'** (Binfield 2004) **of the Luddite debate occurring concurrently with each turning point**.[4] However, the rise in the trend of that usage since the start of the ICT revolution has been dramatic. A proportion of that trend could be attributed to the simple fact that, while the NGRAM is weighted to accommodate the overall change in volume of printed matter at any point in the corpus, two of the occupations that have increased during that time period are academics and journalists (Sobek 2006a) and the topics of innovation and technology in general – and its history – have been increasingly on their agenda.[5]

[4] See the Appendix of the Beyond 4.0 Historical Background Paper, Perez and Murray Leach (2021) for a discussion of this methodology and its limitations.

[5] Although a number of academic roles peaked in the 1970s, according to the data for occupations, tables Ba1159-1395 in *Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition* (Sobek 2006a and b). The dramatic rise of the use of the word innovation in the past forty years is illustrated clearly by Google NGRAM. We have not included the figure here; it is easily replicated via the Google NGRAM Viewer at https://books.google.com/ngrams.

Figure 2
nGram of the use of the term Luddite in the Google Books English corpora, 1800-2020



Source: Michel et al. (2010)

This lends weight to the central concern of Frey's recent compendium of the fears and realities of job loss due to technological change. Synthesising a huge body of academic work on the matter, his book, *The Technology Trap* (2019) warns that public sentiment against technology is on the rise. His argument adds to what appears to be, from our survey of the literature, the dominant position in the academic and policy-oriented future of work debate: that **while there is reason to be more optimistic about the productivity potential of computing, robotics and artificial intelligence (AI) than current figures** – and some critics, such as Gordon (2016) – **would suggest, there is less reason to be optimistic about the future of work** (see, for example, Brynjolfsson and McAfee 2014; Haldane 2015; Trades Union Congress 2017). This near future is predicted using data that shows a decline in wages for lower-skill work and increasing polarisation between low and high-skill work, with a 'hollowing out' of the middle (Acemoglu and Autor 2011), and on projections that calculate the increasing replacement of human jobs by robotics and AI (Frey and Osborne 2013). Frey attributes these changes to the new technologies of the ICT revolution, and compares the present to the pre-1840 years of industrialisation. He builds his argument on the work of Acemoglu and Restrepo (2018), and in particular, their analysis that the 'displacement effect' of automation has, historically, been balanced by the 'reinstatement effect' of the creation of new, labour-intensive tasks (a position with which the five surges model would concur, as we shall discuss further in sections four).

3.2 Different technologies; different effects, and reactions

Frey reasons that the destruction of machinery that occurred in the Luddite rebellions took place because it occurred during a time of 'labour-replacing' rather than 'labour-enabling' technologies.

He draws on historical empirical data, which demonstrates that machine-breaking occurred more often in areas where there were not emerging 'alternative employment opportunities' in manufacturing centres for those who lost jobs to machines (Capettini and Voth 2020). **Extrapolating from the framework that Acemoglu and Restrepo propose for analysing the impact of automation and AI on the demand for labour, wages and employment in the present**, he argues that technology was labour-replacing during the first 60 or so years of the Industrial Revolution. This, he contends, explains 'Engel's Pause' (Allen 2009): the failure of overall economic growth to improve living standards for the majority during that period – a topic of debate amongst economic historians on which there is a large body of literature.[6] This gap between overall output and wages started to shrink in the 1840s, with a real wage growth of 123 per cent by 1900 (according to Allen's 2009 analysis; more on the limitations of the data behind this analysis in section three). Frey notes that by this point the impact of the steam engine was beginning to show in the productivity figures (2019, p.107; citing Crafts 2004); the number of children in the labour force had fallen, depleting the pool of low-cost labour; and machinery was becoming more complex, thus requiring the labour of more skilled operatives. **Attacks on new technology did not occur in the later years of the nineteenth century, nor the twentieth, he argues, because the technology of that period was labour-enabling, creating well paid jobs for both increasing numbers of 'white collar' workers and semi-skilled blue collar operatives**. He attributes the industrialisation of Britain to the growing competition between nations for international trade; an 'incentives' approach to explaining the Industrial Revolution (Clark 2012) that focuses on just one element of the mercantilist background to industrialisation (O'Brien 2006). In his telling, prior to this shifting of priorities on the part of the state, such was the strength of popular opinion against job-replacing machinery before the industrial revolution that innovation was not allowed to flourish, and productivity stagnated.

Continuing to draw on the work of Acemoglu and Restrepo (2018), he posits that the ICT revolution is demonstrating the characteristics of another Engel's Pause; that **with the rise in automation and hollowing out of middle-skill jobs, technology is again labour-replacing**. While siding with the techno-optimist – and the neo-Schumpeterian – view, which holds that the productivity benefits of the ICT revolution have yet to be fully realised, his concern is that, as with the first Industrial Revolution, in which 'the full benefits … took more than a century to be realised' (p.111), there will be a lengthy period of diffusion before these benefits are felt by the majorities – and that in the meantime, we are starting to witness anti-technology protests of the like that have not been seen since the Luddite rebellions.[7] These, in turn, are drawing governmental responses which threaten to restrict the development and diffusion of technology, thus potentially damaging that productive potential in the long term. His concern is that if these neo-Luddite fears are not addressed – and, practically, if new jobs are not forthcoming for those made unemployed in this time of labour-displacing technology – the world may return to what he sees as the 'technology trap' that he argues was the status quo prior to the Industrial Revolution, 'in which labour-replacing technology was consistently and vigorously resisted for fear of its destabilizing force' (p.xiii).

[6] See Blum and McLaughlin 2019 for a discussion of the literature on this topic

[7] This argument is not unique to Frey; fears of a neo-Luddite revival were particularly pronounced around the turn of the millennium (Jones 2006). Frey's reasoning has echoes of the argument of the futurist and singularity proponent Ray Kurzweil (1999), who claimed that Luddite sentiment died out in the 19th century due to rising prosperity, but will rise again due to the revolutionary changes that will happen in the 21st century due to machines with artificial intelligence.

We shall shortly return to quantitative data upon which this argument rests shortly. Here, we wish to address the claim that the anger towards and fears of technology expressed by the Luddites have not reoccurred until the present ICT revolution. As already noted, studying Google NGRAMs for a gauge of the popularity of terms in written material indicates some correlation to the term 'Luddite/s', suggesting a revival of that 'discursive continuity' (Binfield 2004). Furthermore, if this search is expanded to include related terms, this pattern is reinforced. **The use of the term 'technological unemployment' shows a dramatic peak in the 1930s**, corresponding with Woirol's findings in his survey of the literature (1996) and the concerns voiced around automation and secular stagnation at that time (Hansen 1938). An NGRAM of **the 'machinery question', although clearly demonstrating a peak in the 1840s, the turning point of the second revolution of the model, also shows a trend occurring from the late 1880s until the 1920s**.[8] And this is consistent with our survey of the literature; **fears specifically focused on 'machines' persisted throughout the Victorian era and into the early decades of the twentieth century, after which point the diffusion of machinery across Western societies was so ubiquitous that the fears shifted towards 'technology' and its implementation**; more on this shortly.

Yet **while a pattern corresponding to the five surges model can be discerned, other peaks of protest or public concern appear to challenge that pattern**. The Luddite rebellions occurred during the middle of the Great British Leap, the deployment phase of what the model identifies as the first revolution. The NGRAM of 'structural unemployment' peaks in the 1960s, at the same time as academics and pundits, discussed the potential perils of a future of leisure: this as the post-war Trente Glorieuses came to an end, at the maturity of the fourth revolution (Michel et al. 2010; Woirol 1996; Havemann 1964;). **The many protests that have occurred have** had **multiple triggers and, although both union-type organisations and populism have tended to recur in the turning points and at maturity**, the uniqueness of each technological revolution and the response by each government makes it difficult to identify a clear pattern.

But **neither does the literature lend credence to Frey's argument that, as during the nineteenth century and throughout the twentieth century, workers did not attack machinery, one can infer that technology was seen as 'working in their own interest'** (Frey 2019, p.143). In fact, fears around mechanisation, automation and the reduction of the human being to a cog in the machine, to the 'labour' or 'worker' input of production function equations, were rife throughout the nineteenth century and continued into the twentieth (Jones 2006). Such fears – and hopes – dominated the discussions of nineteenth century intellectuals around the rise of liberalism and socialism (Marx 1867; Berg 1980; Jones 2006) and Cold War era future forecasting (Ellul 1964; Havemann 1964) and, as Jones (2006) discusses at length, were expressed in popular culture in literature and later on film, from Frankenstein (Shelley 1818) to Chaplin's epoch-defining *Modern Times* (1936) to the "culturally significant" *The Matrix* (1999; selected for its influence by the Library of Congress' National Film Preservation Board in 2012). At the turn of the last century, the 'horror of a very modern, mechanised form of warfare' in World War I added urgency to these fears, and can be

[8] It also surges again from the 1980s, although given that it had fallen out of popular usage by that point, this is most likely attributable to a rise in academic work on the history of 'the machinery question' – and a rise in the number of academics (Sobek 2006b). This is consistent with our survey of the literature, although it was beyond the scope of this project to provide systematic confirmation of this.

seen as an explanatory factor for the wave of socialist and anarchist-supported uprisings in the 1910s and 20s (Albertson et al. 2021, p.31).

3.3 Regulation and the early shaping of technology

Less existential **fears regarding specific innovations and the technological systems that grow around them change as the technologies embed into society and are superseded with incremental or more radical new innovations**. Early automobiles were steam-powered locomotives, and considered such a threat to human and livestock wellbeing that various 'red flag' laws were enacted in Britain and in the US, named for the stipulation that a man was to walk in front of the speed restricted vehicle waving a red flag. Perhaps the most extreme iteration was passed unanimously by the lower house in Pennsylvania as late as 1896, insisting that vehicles be dismantled and hidden in bushes on sight of any approaching cows or horses, so as not to spook them (Karolevitz 1968, cited in Munger 2018). Yet that same year the Locomotive on Highways Act in the UK removed the flag requirement and raised the speed limit – although only to 14 miles an hour, a figure which was debated hotly as previously the definition of 'furious driving' was determined by the condition of the horse being driven (Hansard 1896). As the number of automobiles on the road increased, these fears morphed into fears of road traffic collisions and pollution, first petrol, then diesel; current concerns regarding emerging automobile technologies include the drain on global energy from the manufacture and charging of electric cars (Deb 2016), the physical dangers and ethics of driverless cars (Wolmar 2020) and the employment and psycho-geographic impact of replacing delivery drivers with driverless vehicles and drones (Leonard et al. 2020).

Contrary to the picture painted by Frey, in which the state-regulated technology until the competition for global markets convinced politicians to let innovation do its work, the **fears that have accompanied the emergence of new technologies have consistently led to policy making that has limited the application of and/or changed the direction of development of that technology**. And while these may not, on initial analysis, seem directly related to the job-replacing or enabling powers of the technology, in the example of the automobile above, for example, the 'red flag' laws and speed limits were lobbied for by the railway companies and those whose livelihoods depended on horse-drawn vehicles, and equally were challenged by those who favoured the development of the automobile. Resistance to technology must be interpreted in context: as Bruland (1995) notes: "It is not simply a matter of specific workplace interests being threatened by new technologies, but a much wider process concerning the ways in which technologies accord or clash with social organizations, cultural values, and so on."

3.4 Understanding Luddism

Binfield's (2004) extensive collection of letters, poems, editorials, banners and other primarily sources underpins **today's scholarly consensus that those who followed the fictional General Ludd were not the technology-fearing late adopters of their mythos** (Randall 1995; Schot 2003). The Luddites were machinists, of looms and weaving machines, and **their anger was not about the adoption of new technologies per se but rather the fact that they had no agency in the manner in which they were brought in**: at the great changes being wrought on the existing ethos and working culture of the guilds; at 'the "freedom" of the capitalist to destroy the customs of trade […] beating-

down wages, under-cutting his rivals, and undermining standards of craftsmanship' (Thompson 1963, p.549; cited in Jones 2006). The actions of the factory owners whose machines were targeted occurred in the context of state actions that enabled this shift: the ending of restrictions on the number of looms permissible in a factory; repeal of the protective legislation in the woollen industry; and the dismantling of protections to the apprenticeship system, which opened the doors to the employment of unskilled and child labour (Thompson 1963; Randall 1995).

These disparate groups lumped under the Luddite banner also drew on the rhetorical traditions and public humour of the day; their presence had 'swagger' and was 'larger than life' (Coniff 2011). Examined in this context, the destruction of machines (and the publicly stated threats that accompanied these events) can be seen as performative, symbolic of their anger at their loss of autonomy. The primary sources tell a narrative of protest that is far more broadly political and sophisticated than a concern with mere machinery, informed by contemporary writers such as Paine (1791) and the recent revolutions in the United States and France; fuelled by sacrifices and hardships of the Napoleonic War the food shortages that ensured (Hobsbawm 1962; Albertson et al. 2021). It was carried out against a backdrop of radicalism, and indeed at times sucked the energy out of other methods of dissent available (Navikas 2016). Their goal was not to halt technological progress, but control over their human capital; a 'fair' wage for themselves and their families; the security that those employing them did not have the power to upend their lives (Binfield 2004).

Crucially, to extrapolate from an attack on machinery in the early nineteenth century that the lack of direct attacks on machinery in the late nineteenth or twentieth century signifies a telling change of heart on the part of those using the machinery is to fail to locate protest in time. Frey discusses the role of the unions in negotiating prosperity in the post-war landscape (2019, p.275-6), and acknowledges that their rise in the late nineteenth century might reflect 'the relative absence of Luddite sentiment' from the 1840s on. However, despite recognising that the US 'may have had the most violent labour history of the industrial world' (p.143), his argument that 'unionised workers didn't focus their anger on machines' (*ibid*) because that technology was labour-enabling and therefore seen 'as working in their own interest' (*ibid*), fails to acknowledge the great shifts that had occurred both across the technological and socio-cultural landscape. Prior to the 1830s, the number of machines and factories was limited both in number and in geography; this is one of the many reasons that the five surges model views the period up to that time as a discrete 'proto revolution', one that set the stage for the installation of the steam and rail of the second revolution and the Victorian Boom that followed (Perez 2002, see Table 1). The Luddites and other contemporary protestors who used machine-breaking in their 'repertoire of contention' (Tilly 1993) lived at a time of 'reassuringly clear-cut targets – machines one could still destroy with a sledgehammer' (Jones 2006, p.8). This remained the case into the 1830s, the period that the five surges model sees as the installation of the second revolution, which was accompanied by the machine-breaking actions of the Swing riots – the protest of agricultural workers worn down by decades of dwindling autonomy and increasing poverty at the hands of landowners and two particularly bad harvests (Hobsbawm and Rudé 1969; Capettini and Voth 2020).

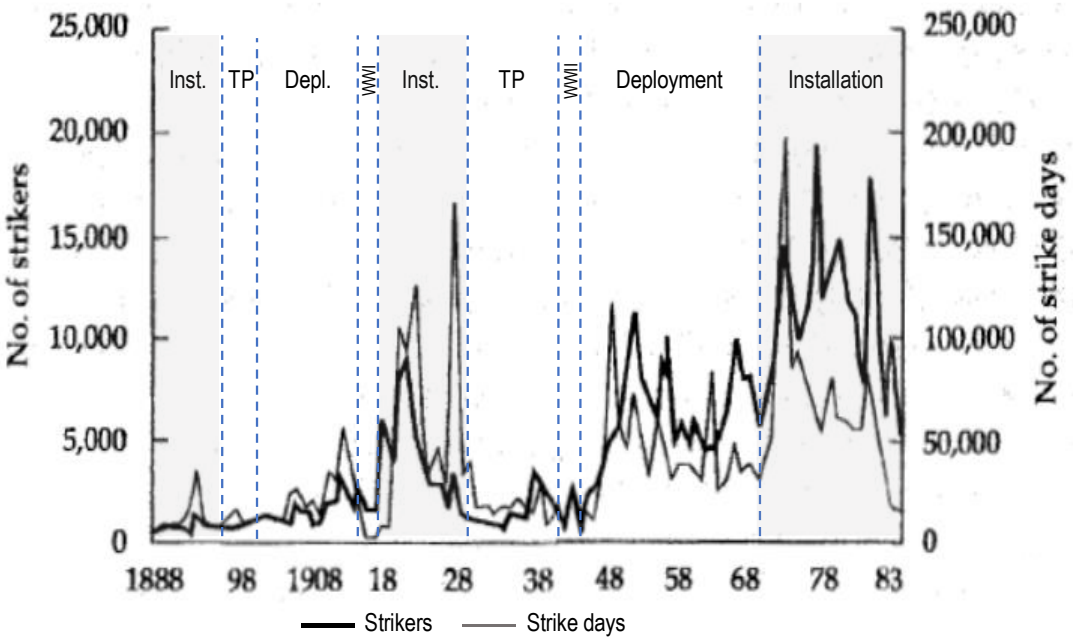
Yet by the deployment phase of that revolution, the 1850s, machinery had multiplied and, more importantly, had become far more complex, more inhuman and monolithic, less assailable. Not only was the destruction of those machines by a small group of workers far less accomplishable in practice; the cultural context had shifted, to one where the practical technology behind the

machines was ubiquitous, an accepted part of life, even if the application and impacts remained great cause for concern. Tilly's research of protest action notes that in his data, after 1831, they find only 'two attacks on threshing machines and three episodes of industrial machine-breaking' (1995, p.331). In 1844, Engels could observe that England was now in what he called the 'third stage' of labour revolt: of strikes, marches and 'attacks on knobsticks [strikebreakers]'. In this taxonomy, 'crime was the first, 'machine-breaking the second and revolution the heralded fourth (cited in Tilly 1995, p.25). Not only was machinery becoming a less tangible target, but by the 1840s, there 'is a sense in which the working class is no longer in the making, but has already been made' (Thompson 1966, p.809). **While the first 'proto-revolution' did not lead to higher wages for the majority** (and the data on this is contested by some scholars, see Clark 1997), **it had 'lifted' an, albeit small, section of the population into new levels of wealth – the urban industrialists – and created a new lens through which those who laboured in their factories saw themselves**.

3.5 Repertoires of contention

Furthermore, it is important to understand that in the later surges, **different repertoires of contention occur at different moments in time**. Populist protest and the strikes born of frustration now regarding job displacement and all the other uncertainties and inequalities brought by creative destruction are common during installation. Strikes with specific demands related to pay and working conditions are common during golden ages, when unions are stronger, and feel confident of their capacity to win the confrontation. They peak again at the maturity of each surge, when the improvements regularly gained based on productivity increases tend to stop. And this worsens when business has recourse to either new job displacing technologies or to moving production elsewhere, which characterise installation periods. Figure 3 shows the intensification of strike action across the last two surges in deployment and installation.

Figure 3
Changing intensity of strike action in numbers and days as technologies propagate
US, UK, France, Germany and Italy – 1880-1983



Source: Freeman and Louçã (2001, p. 358), with data from Gattei (1989). Our period indications.

It should also be noted that in Turning Point recessions, the weakness of labour movements prevents them from action, despite the hardships of those years. The figure also reflects the lack of strikes during wartime (although they are rarely zero). The more typical rebellions in Turning Points are political, against the incumbent parties and supporting messianic leaders against the establishment. Such were William Jennings Bryant in the 1890s in the US and Hitler in the 1930s in Germany, and the many extreme right and left-wing leaders today. Though radically different in political views, they provide hope of redressing ills.

Thus far, we have discussed what the historical record tells us about the fear correlated to new technologies: existential fears, fears about the practical dangers of new technologies, and fears that technology would take jobs. And at its root, **new technology as a proxy for lack of power, agency and welfare**. But the theories of Frey and other future-of-work scholars primarily rest on the quantitative data that purports to tell the empirical story of employment and inequality – and how both have been affected by techno-economic growth. It is to that data that we turn next.

4. Empirical Realities or Normative Assumptions?

> *In travelling backwards from the twentieth century to the nineteenth the student of wages passes from a highway to a thorny path; but in passing to earlier periods he crosses into a morass with but few firm places.*
>
> (Mitchell 1988, p.338)

4.1 Introduction

While there are always limitations to the conclusions that can be drawn from discrete quantitative variables, taken out of context of their functioning within the broader techno-socio-economic system, historical quantitative data comes with additional precautions. Lack of consistency in collection, loss of records and inclusion bias affect the primary source material. Our colleagues in the other BEYOND4.0 teams consider quantitative data from 1970 to be 'historical' for good reason; the older the data, the more likely that much of the analysis is based on secondary sources, so that even revisions to interpretations may still be based on the datasets collated by scholars in the past.

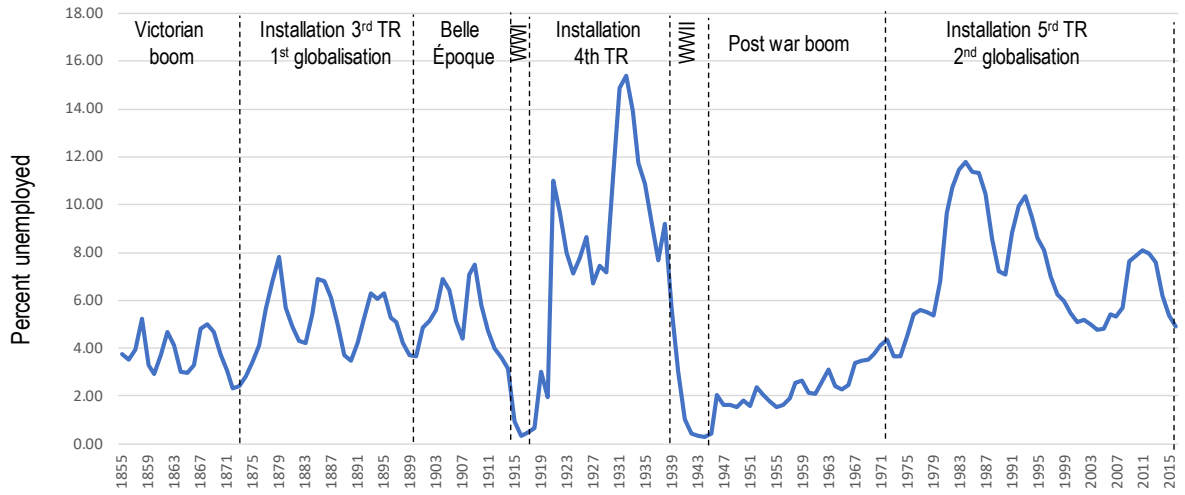
4.2 The typical difficulties of historical data

As Broadberry et al. note in the book that accompanies the release of the Bank of England's 'A Millennium of Macroeconomic Data' (Thomas and Dimsdale 2017) the historical data of technological change in the UK is 'drawn mainly from the large secondary literature that has developed over more than a century of quantitative investigation by economic historians and, consequently, constitute the best that can be achieved on current knowledge' (2017, p.177). 'Large', however, is perhaps wishful thinking; for while there is indeed a 'vast empirical literature' on the causal factors of economic growth (Hulten 2001) and historical employment (and unemployment), a closer look at that dataset echoes what is apparent from even a cursory survey of the future of work literature – which is that **the data rests heavily on the research of a small cadre of scholars** (such as Dean and Cole 1967; Feinstein 1972; Maddison 1982; Mitchell 1988; Hoffman 1965 for Germany) which have then been re-evaluated and revised by others. The analyses and collation of the figures may be different, but until fairly recently, the data itself has been from limited primary sources.

Yet as far as countering 250 years of fears about imminent job losses due to technology, **the data, with all the limitations, 'tell a remarkably consistent story'** (Haldane 2015, p.7). The displacement – or 'labour-replacing' effects do not, even in the relatively short term, lead to huge drops in the numbers employed; rather, the compensation – or 'labour-enabling' effects of technological change have - meant that **employment figures have fluctuated around the same rate despite ongoing population growth, waves of immigration and the (official) entry of women into the workforce** (see Figure 4 for the UK with our periodisations; see Romer 1996, for example, for the US). This alone

counteracts the 'lump of labour' fallacy that there is a finite amount of work, which, although regarded as an artefact of bygone economics, is nevertheless present in the debate on the future of work (Krugman 2003). **The combination of technology and human enterprise has not just created new jobs in the past; it has created more jobs.**

Figure 4
Percent unemployed - Great Britain 1855-2016

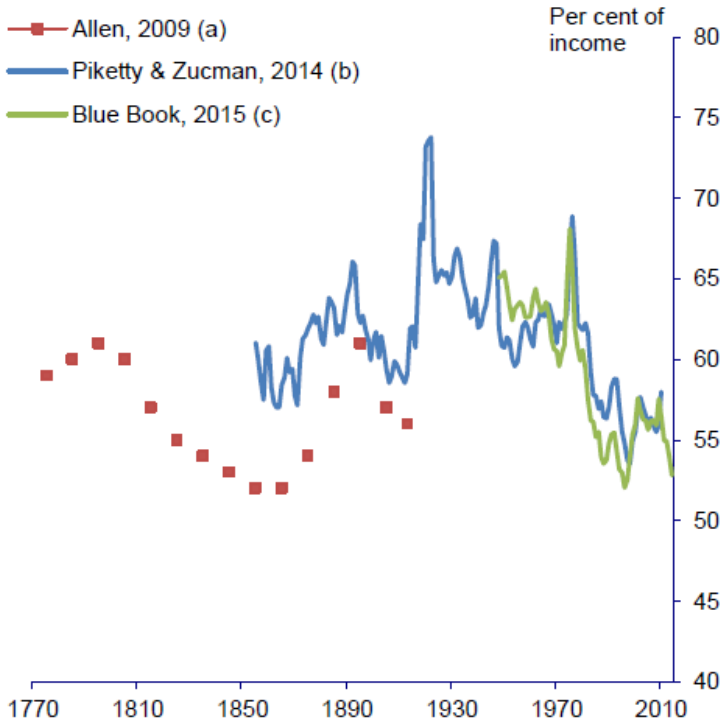


Source: Thomas and Dimsdale 2017, A50-J. Authors' graph and period indications.

4.3 Yet job creation is consistent

Not only does the data show that new jobs have been created; it also indicates that labour's share in national income in those countries has remained, in the long run average, the same (Allen 2009; Haldane 2015). While the new technologies of each revolution have, through mechanisation or automation, increased the productivity of previous tasks, leading to jobs which accomplish those tasks that are either different in degree or entirely new in kind, **the automation process has, historically, not seen a consistent reduction in the share of national income that goes to labour**. Figures presented by the Bank of England suggest that, in Britain, from the industrial revolution in the 1770s to recent times (2010), the share going to labour has fluctuated between fifty-five and sixty-five per cent, with short and infrequent spikes and troughs (Figure 5).

Figure 5
The British labour share of income since 1770



Source: Allen (2009); Piketty (2014); Piketty and Zucman (2014)
Notes: (a) Taken from Allen (2009) and Piketty (2014). (b) Constructed using data reported in the supplementary tables to Piketty & Zucman (2014). (c) These data are consistent with the ONS Quarterly National Accounts Q2 2015 release. Self-employed labour income is imputed differently than series (b) due to data availability.

Source: Haldane (2015; fig. 15)

Thus, successive revolutions, bringing successive leaps in productivity, have not resulted in a major reduction in the share of labour or, as some might expect, in the amount of employment. Rather, 'periods of intensive automation have often coincided with the emergence of new jobs, activities, industries and tasks', many of which are labour-intensive (Acemoglu and Restrepo 2018). At the most technologically-ambitious – or pessimistic, depending on their outlook – end of future forecasting, there are those who believe that the exponentially increasing abilities of robotics and AI to replicate human movements and thoughts threaten this pattern; that although new tasks will surely be created, it is robots that will do the lion's share (Ford 2015).

However, the majority of analysts do not consider that this will occur anytime soon, if it does so at all (Acemoglu and Restrepo 2018; Autor 2015). Rather, it is the trends in wage levels and of productivity of the labour-intensive jobs of our current moment that has those in the future-of-work debate worried. And yet on these matters – and particularly on the relationship between the two – the historical record is far less clear, and thus future projections rife with assumptions.

While there are those, like Cowen (2011) and Gordon (2016), who have concerns that the productivity increases of the twentieth century were exceptional, and, like Crafts and Mills (2020), that the current slowdown in figures is unprecedented, the more optimistic thread in the discourse is that overall productivity may be currently mismeasured, in particular in regard to the impact of intangibles (Byrne et al. 2016; Grifell-Tatjé et al. 2018; Goldin et al. 2019; Brynjolfsson et al. 2021). However, **the concern here is that the data at our present transitional moment indicates that the wealth generated may not – unlike in the past – benefit the wages of the majority without significant policy change** (Brynjolfsson and McAfee 2014, Acemoglu and Restrepo 2018, Frey 2019). This projection is, in part, an extrapolation of current trends: in particular, the decoupling that has developed over the past forty years between productivity and wages, the so-called **productivity pay gap** (Bivens and Mishel 2015; Gould 2020) and the significant rise over the same period in the **shifting of jobs to the service sector** (Wilkes 2021).

However, it also rests on analysis of the historical record which finds that each technological shift (based on the three revolutions model used by Frey) has seen a 'hollowing out' of middle-skill jobs (Grey 2013; Katz and Margo 2013). Not all concur with the finding that this hollowing 'has widened and deepened with each new technological wave' (Haldane 2015); Katz and Margo caution that while this occurred in manufacturing between 1850 and the early twentieth century, in fact in the aggregate economy it was the low skill jobs that decreased, while 'middle skill jobs remained steady,' again highlighting the limitations of economic theory that is based on the study of industry. (2013, p.3). Yet there is **a commonly held view that the significant upturn in the destruction of middle-skill jobs that has occurred since the start of the ICT revolution is only likely to be exacerbated by the nature of robotics and, particularly, of AI, which are now replacing white-collar jobs in addition to the blue-collar industrial jobs already in decline** (Frey and Osborne 2013).

What typically goes uninterrogated in the skills-based discourse are the normative assumptions underlying concerns over what is seen as the resulting increase in the wage gap between skilled and unskilled employees – the so-called 'skill premium' (Krusell et al. 2000; Fragkandreas 2021b). As Frey (2019, p.221) himself notes, the blue-collar workers of mid-twentieth century America were able 'to attain a middle-class lifestyle on the basis of nothing more than their wages' – but this was not a result of the skill-level of their assembly line work. Low-skilled service workers also commanded wages that permitted them to participate in the suburban mass-consumption of the American Dream (Perez 2002). We shall return to this conflation between wages, skills – and productivity – shortly.

4.4 But labour's share fluctuates

As already noted, in Frey's telling of the historical narrative, we are currently in a similar moment to 'Engel's Pause', the long period of installation that occurred before the increased productivity of what he recognises as the first Industrial Revolution began to trickle down to the wages of the workers (Frey 2019 citing Allen 2009). Unskilled women and children were 'the robots' of this revolution (Frey 2019, p.8), ousting the skilled craftsmen who protested under the Luddite banner in an era of dark satanic mills and stagnant wages. According to the data Allen uses, the rate of return to capital rose over 20 per cent while the share of income allotted to labour dropped (Allen 2009). **Yet, given the lack of data from that period, and the dubious reliability of the available data,**

there is controversy that the living standards paradox actually existed. Clark (2007) finds that real wage growth was underestimated and that GDP growth was overestimated. That latter point echoes the long-running debate over the productivity growth in that period (Hoffman 1956; Harley 1982; Crafts 1985). While there is no doubt that then, as now, the few profited at the expense of the many – O'Brien estimates that at the beginning of the 19th century, the top 10% of income earners probably received nearly half of the nation's income, while the very top 5 per cent obtained about a third (1989, p.347) – dark satanic mills were not a ubiquitous reality of that period of British industrialisation; many manufacturing industries, such as boots and shoes, remained small-scale and outside the factory system well into the middle of the 19th century (Temin 1997).

Furthermore, as we shall discuss in relation to lifestyles in the next section, the research on consumption which Frey uses to demonstrate the lack of a rise in living standards can be parried with other research that shows a marked change in the way that segments of the population consumed (Allen and Weisdorf 2011; Broadberry et al. 2015). Not only that, but there is a complex web of causal factors that led to the hardships of urban workers in the early nineteenth century: the aftermath of the Napoleonic Wars and the disruption that brought to the labour force as soldiers returned; the reduced capacity of domestic agriculture at the same time as transportation costs and the Corn Laws removed the option of cheap imports; and a series of bad harvests (Hobsbawm 1962; O'Brien 1989; Broadberry et al. 2015; Albertson et al. 2021). To attribute already dubious data on income distribution to 'a schematic two-factor model' (labour-replacing technology) risks attributing false causality (Mokyr 2019).

Yet this particular point of contention is just one illustration of the problems with historical data and of relying on growth accounting perspectives to extrapolate future society-wide shifts. We have already noted that many of the analyses and datasets are simply revisions of the limited data available, using different methods of estimating or estimating different elements. Thomas and Dimsdale (2017), for example, include a major revision of the Feinstein figures, using estimates for total hours worked, which is key given the changes in working hours that occurred over the second half of the nineteenth century (Broadberry 2017). This both brings into question older analyses resting on the Feinstein figures and at the same time challenges the notion that this is really 'new' data. The fact remains that our historical datasets are at best extrapolated estimates. Cumulatively, the data can help us to build a broad picture of historical realities, but it is not wise to make claims without taking the much wider context into account.

4.5 The omissions deepen the unreliability

The problem, however, is deeper than methodology. Employment figures, wages and the contributions of occupations and even entire industries are omitted, 'from metalwares, chemicals, glassmaking and pottery to food processing'; such industries were dominated by small and/or family firms whose accounting records were incomplete and/or lost over time (Berg and Hudson 1994). There is also a false assumption that figures from the (relatively) recent past of the late nineteenth and early twentieth century are more reliable than the scarcer data from earlier years, yet 'we know much more of [the Crowley Iron Works] in the seventeenth century than about the typical early nineteenth-century manufacturer of metals in Birmingham' (ibid, p.147); much rests not only on

whether records were kept and then stored but, if so, on whether there has since been any analysis of those primary sources.

Also omitted is the majority of work done by women. Unpaid household work has typically not been recorded in national accounts, although there have been ongoing attempts to measure non-market production since at least the 1930s (Waring 1988; Bridgman et al. 2012).[9] Not only does this exclude a sizable proportion of the economy (recent government estimates for the UK put 'overall unpaid household service work … equivalent to 63.1% of gross domestic product (GDP)' in 2016 (ONS 2018), but, historically, work women performed outside the home was also often 'not counted' (Waring 1988; Berg and Hudson 1994; Shaw-Taylor et al. 2019). Frey writes at length on the low-paid labour of women and children, the 'robots' of the first half of the nineteenth century, yet does not seem to consider that the poor documentation of non-adult males might affect the productivity and wage statistics – and lead to an overestimation of the contribution of those sectors dominated by male labour, such as building and general labouring (Berg and Hudson 1994). Outside of the factories, in farming, craft industry and services such as shopkeeping, women – and especially married women – were often not registered as employed, yet 'played a full part in directing the [family] enterprise' (Floud 1997, p.12). Additionally, more recent research at the micro-level is showing that there were more women employed in the professions in the past than the gender-biased authors, and therefore, academic articles of the nineteenth and twentieth century have led us to believe (Corfield 2012).

It is not only gender but also race that has been omitted from the statistics. While there is extensive focus in Frey (2019) and amongst scholars of technological change and economic growth of the importance of the cotton industry in the industrialisation of Britain, less attention has been paid to the impact of slavery and of colonisation – both as a source of import supply and export demand and as a source of off-shore labour that is typically overlooked from the productivity-labour statistical nexus.[10] Some recent estimates have been made in the United States to account for slave labour on US soil (Rosenthal 2018; Hacker 2020), and there is convincing evidence that the uncounted labour of both the 'sea island' Caribbean cotton plantations, and later those in the southern US, were critical to British innovation and productivity growth (Styles 2020; Berg and Hudson 2021).

Aside from blanket omissions, there is the issue of apples and oranges. In his review of Maddison (1982), Adams, who both 'admires' the book and finds it lacking in novel theory, concludes by stating:

> *'a final demurral: What does it signify to estimate a GDP for France or Europe in AD 500, 1500, or even 1820? Was there even a France or a Europe at those times? Was there an Italy in 1850? Was there a unified market economy with significant prices? Have not goods mixes changed, along with the nature of work? Has not society's estimation of the value of material things altered? Did medieval monks watch television - or is there equal utility in perusing illustrated Bibles?'*

[9] There are exceptions: it was included in the Norwegian national accounts for the first half of the twentieth century, until revised along international standards.

[10] There is a long-running debate in economic history on whether slavery created the wealth that financed the industrial revolution, following the publication of *Capitalism and Slavery* (Williams 1944; see Harley 2013).

(Adams 1986, p.396)

Much of the data on employment comes from census records, yet the classifications of jobs have changed with every census taken (Wyatt and Hecker 2006).

We shall return to the issue of context and the problem of comparisons across paradigm shifts shortly. But if one agrees with Adam's comment regarding macroeconomic indicators, where is the value in studying the patterns of the past? We would argue that analysing such data alongside both micro-economic data and sociological research into the successes and failures of industries and occupations in their temporal and geographical context – taking a systematic approach and welcoming complexity, in other words – can offer a more nuanced appraisal of why, how and what worked to unleash the technological potential and subsequent societal gains within each specific surge.

4.6 Attempts at rectifying the picture

Even at the disaggregated industry level, the limited availability, and lack of standardisation of, sources can make analyses deceptive. Take, for example, studies on the history of shipbuilding. Feinstein's (1972) data is widely used: his price index is based on the cost data for new vessels reported in Maywald's (1956) value estimates of the British merchant fleet, which does not take into account changes in quality or complexity due to technological change – and which in some industries, shipbuilding being one of them, happened over a very short period of time. Pollard and Robertson, therefore, construct an alternative index based on the Fairplay price of a basic 'representative' cargo ship – but only for the later years of the comparison index. Earlier years are calculated with a GNP deflator. Analyses using the two indexes suggest quite different productivity figures; thus using either of the single set of figures would tell a different story (Pollard and Robinson 1979).

There are, however, ongoing attempts to rectify both the gaps in the macroeconomic data and to provide far more detail at the disaggregated level. Projects like the extensive and ongoing Occupational Structure of Britain c.1379-1911 research programme by the Cambridge Group for the History of Population and Social Structure (CAMPOP) at Cambridge, which, since its inception in 2003, has been carrying out a series of regional, industry and occupational reconstructions.[11] Thus far, the findings of their work have challenged the long-held view that the secondary sector in Britain jumped from the late eighteenth century; their research shows that by 1700 over 30 per cent of adult men, and in all likelihood, large numbers of undocumented women and children, were employed in manufacturing. This finding affects the productivity figures, for while the output of the secondary sector increased as industries mechanised, a larger labour force was not needed to produce that output; the increases came from a 'technology intensive' path of powered machinery, not a labour intensive one. Furthermore, they find that contrary to the dominant view (illustrated by the disproportionate number of academic studies on industry and the orientation of economics

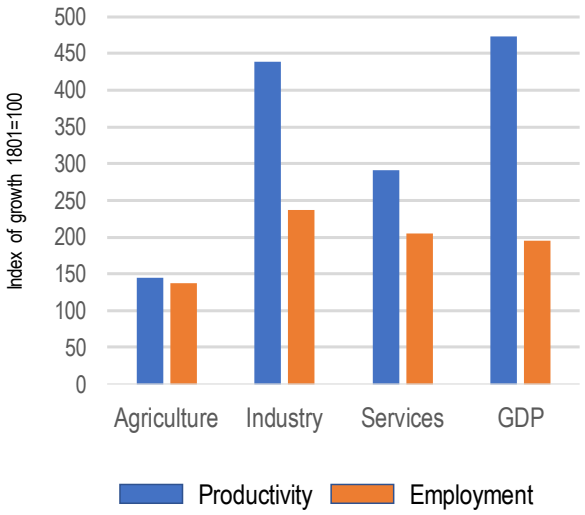
[11] https://www.campop.geog.cam.ac.uk/research/occupations/

towards it (Broadberry et al. 2015, p.130)), the major shift away from agriculture in the nineteenth century was to services (the tertiary sector), rather than to the secondary (industrial) sector.

4.7 Rediscovering the service sector

The CAMPOP researchers are not the first to emphasise the overlooked role of the service sector in nineteenth-century growth (see, for example, Lee 1984; Broadberry 2004). Even the older datasets paint a clear picture that this was the case. **During the first and second revolutions, which were mainly centred in the UK, it is already evident that the growing productivity of industry did not increase employment as much as services did**. Figure 6 covers the deployment period of the first revolution and the installation period of the second. It thus includes the so-called 'Engels Pause' (Allen 2009) when wages did not follow productivity and did not include the Victorian boom when urbanisation multiplied services even more. The data show how output quadrupled, very close to the growth in industry. Agriculture barely moved in the fifty years while the output of services almost tripled. However, **employment in services doubled, as did total employment, whereas that in industry grew half as much as output and in agriculture at the same pace**. One can interpret this as the growth in service employment being a consequence of the growth in wealth created by the higher productivity in industry.

Figure 6
Index of growth of output and labour, by sector and total
Great Britain 1801-1851



Source: Data from Broadberry et al. 2015, table 9.01 p.344. Authors' recalculations.

As the service sector tends to be made up of smaller firms, and ones that do not necessarily use impressive new technologies, their visibility has perhaps been much lower than that of the 'new tech' industries of each surge which, as installation proceeds, tend to become giants. And yet it is

precisely the novel high-tech firms that create the fear of unemployment as they grow. Another contributor to this blindness may be the fact that some of the most important high employment services are not in the private but in the public sector.

For example, at the turn of the twentieth century, when the railways were still the dominant infrastructure, by far the largest employer in the UK in 1907 was the Post Office, employing over 100,000 more than the next largest employer, the London and North Western Railway Co. (although it must be noted that the railway companies combined easily surpassed the Post Office total). The Post Office was also the biggest employer in the US in that year, just ahead of US Steel and the Pennsylvania Railroad; and the second larger employer in Germany (Wardley 1999). But while the importance of the overlooked service sector is not a new finding, the CAMPOP group's research adds considerable weight to the earlier figures. They conclude that while the 'tertiary sector growth is often assumed to date from the 1950s and perhaps to be insecure or unstable … all high-income societies are dominated by the service sector' (Shaw-Taylor et al. 2019). This is crucial because it takes steps towards undermining the narrative that the loss of well-paid middle-skilled work is due to a shift in employment from high-productivity industries to the service sector.

This question is at the centre of whether wages are strictly determined by skills and by the productivity of the sector or whether, in deployment periods, society tends to recognise the general rate of productivity growth in the economy and shares the benefits more widely, which is precisely why such times are called 'golden ages'. A clear ratification of this was seen when the 'middle income' jobs in the industries of the advanced world became 'low- income' jobs as soon as they were outsourced to China. And in terms of tasks, skill acquisition and education, in keeping with the Adam's (1986) quote above, can you really compare manufacturing jobs in 1950 with professional service sector jobs in 2016? How do you classify jobs in the tech giants of today? Are they in the secondary or tertiary sector? The context is different. Wage levels are not determined by jobs nor skills - like price levels, they are socio-politically determined. That is why a proactive state that gives shape and direction to technological revolutions is so important for society to get the most out of each leap in productivity, once its potential is fully recognised. It is to these issues that we turn in the rest of the paper.

5. Directionality and lifestyles: Demand as the driver for jobs

5.1 Directionality: the social shaping of technology

There is a distinction between a *technological revolution*, the *potential* inherent in that revolution, and **the *direction* of investment and innovation in which that potential is deployed** (Perez, 2013). As discussed in section one, technological revolutions are based on an interrelated set of new technologies, industries and infrastructural networks that develop in intense feedback, providing markets and suppliers for each other. In the process, these revolutions also provide a new potential to transform and enable innovations in all other industries. The possibilities inherent in the application of those technologies are disparate and sometimes unconnected. They can be used and shaped in different ways, and **profitability depends, not only on the power of the technologies, but also on relative costs, dynamic demand and the availability of synergies in terms of suppliers, skills, distribution networks and customer learning**.

To understand why this is so, one must turn to the scholars of innovation. The Neo-Schumpeterian understanding of innovation is that products are not developed in isolation but as part of technology systems (C. Freeman, 2008). Each innovation creates problems that call forth solutions from suppliers, which then spur investments and can lead to entire new industries (Rosenberg, 1983). **A common orientation for innovation, applicable across multiple and disparate industries, new and mature, of all sizes, provides convergent trajectories along which these industries – and institutions – can innovate, generating synergies** (suppliers, skills, equipment, service and distribution networks, demand patterns, etc.) **that provide advantages for all participants** (Mazzucato and Perez 2015).

Key to countering the technological determinism of the future-of-work debate, then, is not having blind faith in the technologies themselves, or in 'the market' to produce new jobs that will magically reduce inequality. After all, the market, as Mazzucato (2016) has noted, is itself only the outcome of the converging actions of multiple social actors, both inside and outside the firms involved. And the technologies, in most cases, offer a wide range of possible directions and ways of organising their use (Murray and Trist, 1993). **Even if it is in the nature of capitalism for the emergence of revolutionary technologies to be unstoppable**, as Frey and others suggest, **the direction for the deployment of their potential across society is the result of socio-political choices**. Ford's assembly line was used by Hitler, the Soviet Union and the Western democracies, in widely different directions, with the direct support of Ford himself (J.B. Freeman 2018). Companies, consumers, civil society and government all influence to different degrees what is done and not done with the various technologies. Governments, in particular, define the context through the convergence of policies in certain directions, whether or not consciously made as ways of shaping technologies.

5.2 The recovery of employment levels: The example of the great depression in the 1930s

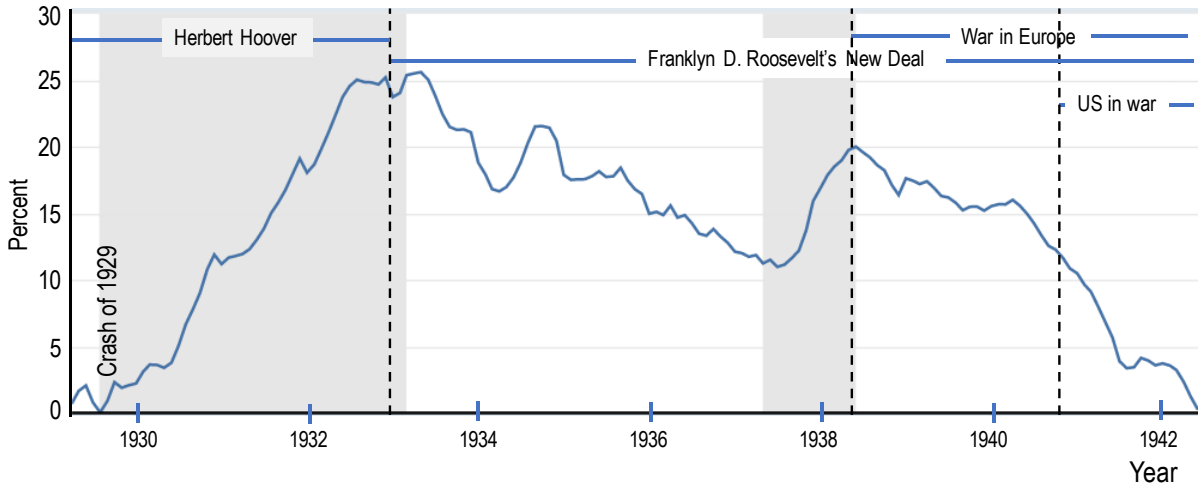
Figure 7 shows the result of two chosen directions in terms of creating jobs and combatting unemployment. After the crash of 1929, the then-President Herbert Hoover, having seen the success of new technologies in the booms of the 1920s, expected the market to revive the economy

on its own, yet unemployment soared unabated. Soon after his election in 1933, Franklyn D. Roosevelt implemented the New Deal. This approach included public investment in everything from the arts to massive infrastructures. Policies were designed to strengthen the unions and promote collective bargaining; facilitate home ownership through the establishment of Federal National Mortgage Association (FNMA, dubbed Fannie Mae) **and provision of government backing for mortgage loans, thereby reducing risk for the banks in lending to employees and thus promoting home building. Unemployment was cut from twenty-five to ten per cent.**

Full employment was only reached with an even more proactive type of directionality: war procurement. From the moment the war started in Europe, Roosevelt found various ways of promoting war production to help the allies against the fascists. When the US finally entered the war after the Japanese attack on Pearl Harbour, the economy was put into high gear to increase productivity and provide enormous quantities of military equipment, using mass production technologies to the utmost, achieving astonishing feats of productivity. By 1944, a gigantic Ford plant was producing 500 B-24 bombers per month (Herman 2012, p. 241).

Figure 7

Per cent of labour force unemployed in depression and war– USA 1929-1945



Source: NBER (2022), retrieved from FRED 'Unemployment Rate for United States, data series m08292a'. Authors' period indications.

So, **whether the unemployment is caused by the crash that tends to end the installation period of each revolution or by the spread of the new technologies, government policy and directionality are the crucial tools** that have brought the greater employment levels typical of the golden ages in the deployment periods (Perez 2009; 2013).

5.3 Government policy as orchestrating a positive sum game between business and society

Such obvious successes in terms of reviving the economy and providing mass demand, facing the depression and the war, made it easier to apply strong Keynesian policies when the war was over. Previously reluctant businesses (and many equally unwilling politicians) finally accepted state involvement in the economy. While the installation period was led by finance, and political leaders in the 'Roaring Twenties' insisted on unfettered free markets, claiming that 'the business of government is business', **the state now stepped in with procurement, partnerships, regulation, high taxation and, most of all, by providing increasing consumer demand through the Welfare State.**

Internationally, the Bretton Woods accords stabilised international trade, but **it was the entrenchment of some form of welfare state which secured the post-war domestic economies.** Free or subsidised education and health care were policy choices informed by the conviction that healthy, educated citizens were necessary for an economy to thrive. Even in the US, a progressive tax-system was implemented on the understanding that businesses stood to benefit as much as society. At the same time, labour unions sanctioned by the state ensured that salaries kept pace with productivity increases, pensions (in the UK) and the GI Bill (in the US) were implemented as promised to soften the blow of wartime conscription, and unemployment insurance was promoted from a tentative, limited, pre-war policy to standard practice across the economy. Along with life insurance and the personal credit system, **these measures established a reliable expectation of growing disposable income across the national population, which in turn facilitated a steady increase in per-household consumption that brought forth successive series of inter-related innovations** spreading across individual domestic markets and overflowing to the rest of the world.

Depending on the specific context of each advanced country, there was a varying degree of expenditure on the two directions guiding the post-war boom – the arms race and the provision of social welfare and good living for the majority of people – both of which contributed to innovation and market expansion. In Europe, the massive reconstruction of the post-war economy was mainly state funded, with the support of the US-provided Marshall Plan. The social security net, already advanced in most countries since the beginning of the twentieth century, was expanded to include universal public health care, state pensions for all and other complementary measures.

The fact that the United States set up less of a welfare state than most of the European countries should not be understood as a hands-off approach. **Apart from the fact that the market was neither unregulated nor unsupported, many policy choices outside of 'industrial policy' gave a general direction to technology at the systemic level and led to important synergies for business**. The GI bill provided veterans with free access to education and easy funding of home ownership. The passing of the Federal Aid Highway Act in 1956 (the largest public spending project in US history) was a conscious, strategic policy decision to facilitate suburbanisation and country-wide transport. The highway network unleashed the potential of the automobile, and opened up cheap land outside the cities for the development of great suburban tracts. In turn, mortgages were publicly backed by the FNMA and encouraged vs rental by the law that allows mortgage payments to be tax exempt (see Jackson 1985). In its turn, the Cold War set the direction for massive frontier innovation, continued the high levels of government military procurement of WWII, and cemented the position of the US (along with the Soviet Union) as frontrunner of a profitable international arms market (Kaldor 1982).

However, as Keynes (1933) had suggested to Roosevelt, it was suburbanisation and home ownership with its car in every garage and its kitchen filled with labour-saving devices that became the trajectory that unleashed the potential of electrification and the Fordist model of production, which had been installed in the decades prior to the war. That was, of course, made possible by the financial security provided by the welfare state.

It is in that context of government shaping and directionality that competitive free markets operated profitably and successfully during what the French have called the 'Trente Glorieuses'.

5.4 Different directionality in each revolution and in each country

The combination of the potential inherent in the new technologies, the unique contextual circumstances of the time and the role of the state in 'tilting the playing field' for successful deployment has been true for all previous technological revolutions.

In the First Industrial Revolution, the growth of mechanised industry–particularly of cotton –was facilitated by the creation of a new transport infrastructure (authorising canals and toll roads, building ports and docks), the exemption of exports from taxes and the suspension of convertibility to gold from the Bank of England, enabling the growing debt for the Napoleonic Wars together with enough credit for private investment. Business was also facilitated by a strongly protective trade policy, and a 'slave-based Atlantic trading system that was state-supported, consciously pursued, and motivated by the possibility of material gains on a scale hard to achieve in the domestic economy of the 18th century' (Berg and Hudson 2021). **The figures may show a limited impact on productivity and standard of living, but the directions taken in this early and localised wave of technical change set the stage for the impact of the second.** They led to a new paradigm of efficiency and productivity and the notion of a capital market independent from the producer and coevolving with government regulation.

The directions which unleashed the potential of steam and the railways in the Victorian Boom were urbanisation, widespread mechanisation and global exports. Britain became the 'workshop of the world' and the first to have a full national trade and communications network provided by the railways and telegraph to every corner of the kingdom (Dyos and Aldcroft 1969). Municipal governments played a major role in urbanisation and the growth of industry and commerce. They were encouraged by the central government, which often complemented the financing (Hennock 1963). They provided the urban infrastructure, with the need for sanitation measures, in particular, leading to numerous public/private enterprises for the provision of public works (Fraser 1984). At the same time, the national government removed all barriers to trade nationally and internationally, including the use of gunboats to force Japan and China to open to commerce (Cable 1971).

The third surge, from the 1870s, was based on a new set of technologies centred on cheap steel and heavy engineering (electrical, chemical, civil and naval). It saw **different governments impart two different directions**. The British empire promoted globalisation, supporting the growth of the global infrastructure — networks of railways, telegraph, ports and steamships — and provided the gold standard, enabling the financial and commercial services that interconnected the world and championed free markets. The US and Europe, especially Germany, as well as Japan, concentrated on their own internal development, promoted urbanisation and industrialisation with strong

protectionism and other bold support measures, including enabling major fusions and cartels (McCraw 1995).

In the US, government-promoted railway construction crossed the country from ocean to ocean and branched out in many directions creating a vast national market both for farming equipment and consumer products. The vast lands acquired by the federal government, by purchase or war, were given as grants (or at low cost) to the railway builders, the farmers and the universities in order to promote markets, develop self-sufficiency and export surplus in food and – copying the Germans – to educate the population and advance in science and technology. **The rate of job growth and the promotion of agriculture led to the opening of the door to millions of migrants**, especially from Europe in the East Coast and from China and other Asian countries in the West.

The directions provided by the German government were also industrialisation and urbanisation. **They practised active protectionism and other forms of support** (Blackbourn 1996; Pierenkemper and Tilly 2004). In particular, they supported and protected the development of a capital goods industry as well as chemicals and metallurgy and advances in agriculture, mining and shipbuilding. Science, technology and education were strongly promoted and funded by the State. The government also accepted and encouraged the formation of cartels to avoid price wars and strengthen existing companies (McCraw 1995). Most European countries followed a similar path.

5.5 The possible directions are not arbitrary

In all cases, the policies that conform to a 'direction' for investment, technical change and growth, **support and guide business towards a synergistic direction and therefore strongly influence the rhythm and quality of job creation** from the range of the possible, enabled by the emerging technologies. They also include the welfare and social security measures that determine whether workers and society at large will benefit less or more from the promises of the new technologies.

However, the direction cannot be arbitrary. What is needed each time is a context-appropriate direction, in the form of coherent and systemic policies intensifying and accelerating existing trends in the economy. If it is to bring forth innovations and investments that are synergistic and self-reinforcing, it must be clearly within the range of what the technological potential has made viable – and tap into production and lifestyle changes already happening and along innovation paths that are being followed by business, precisely because demand responds —and even pulls. It is a question of accelerating existing trends – innovation niches (Kemp et al. 1998) – and bringing them together in a convergent way, in a profitable and aspirational direction, capable of spreading across society and leading to growth and job creation.

5.6 Lifestyles: creating both demand and jobs in services

A key element of a successful direction is that it both responds to, and generates, demand, which also leads to jobs, replacing the ones lost from technical change. **Key to the creation of demand with each revolution has been a change in lifestyle: a new aspirational 'good life', underpinned by new technologies and fostered by government policy**. These new ways of living which become possible due to technical change are often overlooked as simply a by-product of that change, and

yet it is these new lifestyles that shape demand for new products and services, and those products and services which become the major source of new jobs (Perez and Murray Leach 2018).

Each revolution provides a new interrelated set of life-shaping goods and services which emerge initially in niche form. As there is an overlap between the early installation phase of each revolution and the late maturity phase of the previous, these initial experiments with new technologies and ways of living are not necessarily obvious game-changers at the start. Typically, such changes to the status quo begin either at the top of the income and education scales and/or in niche groups seen as radical outliers (Geels 2004). New products and services that are initially expensive are adopted by the elite as 'conspicuous consumption' (Veblen 1899), becoming an aspirational lifestyle for those less affluent. Others may be perceived as too radical, no matter their point in the income scale. While examples of objects and processes that exemplify the former are easily recognised from each period – fine cotton cloth, ceramics, a car, a telephone, the mobile phone – the diffusion of once radical ways of living is not always linked to technological change. This is clear in the current transition, with 'organic' products and practices reminiscent of the 'hippie', back-to-the-land movements of the 1970s now sold at a premium in increasing quantities.

It is the coupling of new innovative products with new innovative ways of living that is key to the lifestyle shift. The new technologies change production methods, at the same time as the gradual increase in demand results in economies of scale, bringing prices down in a virtuous spiral. As this new lifestyle slowly becomes the model of 'the good life', it shapes the aspirational desires of the majority, guiding innovation and investment trajectories as it spreads across society.

This interconnection of products and lifestyles leads to systemic change, affecting both the service and production economies. The innovation of the car and its place in the American Way of Life, as both status symbol and practical mode of transport, led to petrol stations, mechanics, diners, motels, shopping malls, car insurance, and traffic reports, as well as enabling suburban living and suburban industry (Jackson 1985). The development of plastics occurred in a historical moment when resource scarcity was not perceived. It followed a new epoch of mass leisure time as a lifestyle choice (Surdam 2015), leading to innovations that prioritised reducing work in the home and, therefore, 'disposability': multiple plastic materials were developed so that dishes and bottles did not have to be washed or returned; synthetic fibres were designed to create garments that did not need ironing, and disposable plastic packaging was made available for processed, refrigerated and frozen foods. Gardening as a hobby, to give an example not immediately associated with 'innovation', began as a passion project for the wealthy, who employed gardeners. By the mid-nineteenth century, instructional books on gardening for the emerging urban professional classes became available; by the twentieth century, with the practical reality of suddenly having one's own garden – or conversely, no longer having servants – it had become a common hobby, leading to the development of seed catalogues, commercial nurseries and garden centres, implements and chemicals, all requiring investment and leading to new employment (Hadfield 1985).

These activities and the associated employment may have little use for the new technologies and may be of much lower productivity. Similarly, during the Victorian boom, no steam engine was required for the milliners, the boot and dressmakers or even the furniture factories. Yet, such activities were essential for the urban way of living, which depended on the railroads, textile

factories and other advanced technologies of the time. They were an integral part of the way of living and of the profitable production spectrum centred on the second technological revolution.

It is the systemic innovation around new lifestyles that ultimately provides the majority of employment growth for each new technological age. Encouraged by the setting by the government of a synergistic direction for the appropriate context, the transition happens faster and more dramatically. Without direction and context, innovators act at high risk along many different and diverging paths. There are many 'failed' experiments in the Installation years, when – within the potential inherent in the new technology – the 'common sense' of the previous paradigm is still dominant (Perez 2002).

Thus, the first automobiles looked like horse-driven carriages. The driver sat as if holding reins, the engine was measured in horsepower, and the other parts were made by the same workshops that made the carriages. It can take decades to arrive at a design that is consistent with the essence of the new technology. Only 8000 cars were in use in the US in 1900, owned by the very wealthy; by 1913, aided by the emerging credit system, 485,000 of the world's 606,124 automobiles were sold in the US (Gordon 2016). It would take yet another 30 years before demand for a car (or two) in every garage was created by the spread of suburbanisation.

5.7 Lifting successive layers of the population to better lives

While the first industrial revolution was indeed limited in scope and had a devastating effect on workers in the craft industries, as Frey notes, it did create burgeoning new industrial and commercial classes. Town directories from the late eighteenth century capture the rise of 'town gentry' and the diversity of occupations in the 'increasingly commercialized, if still largely pre-mechanised' Britain. This highlights that the growing links between different towns and regions – 'from manufacturing, commercial and professional centres to …. leisure towns and resorts' – was creating 'a confidently shared urbanism, bridging between aristocratic and middle-class society.' (Corfield 2012). Not only was there a new 'middle-class' layer – mainly the bourgeoisie and the merchants – but historians of the period have noted that even for those less wealthy, there was now an aspiration and tendency to buy higher quality foodstuffs and manufactured goods rather than simply more food (Berg 2005; Broadberry et al. 2015). This has in fact, occurred with each revolution: a new part of the majority lifted into the good life. Changing consumption patterns highlight the need to analyse historical data in context, particularly when making comparisons to the present day.

When urbanisation took hold with the second surge, the lifestyle shift was to city-based Victorian living. Comfort and consumption depended on the many domestic, commercial and professional services provided for the new way of living. Businesses, large, small and very small, found inexhaustible demand in the growing numbers of city dwellers, who, in turn, served as test bed for export markets, which in turn provided ideas for further innovation at home. The urban environment cut access to 'non-market-based leisure activities, both secular and religious', and instead, market-based commodities such as 'sugar, tea, tobacco, spirits, calicoes and assorted manufactured goods' were consumed, together with market-based entertainment such as theatre, conferences, fairs and so on. And this was as true for labourers as it was for the elites (Broadberry et al. 2015; p.415). And whereas the 'hollowing out' in manufacturing continued, even as the various

Factory Acts saw women and children slowly replaced by a male labour force, in the aggregate economy middle-skill jobs remained at the same level, high-skill jobs expanded, and it was the low-skilled jobs that declined (Katz and Margo 2013).

At the turn of the nineteenth century, in the age of steel and heavy engineering, the Belle Époque in Europe, in parallel with the Progressive Era in the US, encapsulated the good life of the day. During this first period of globalisation, the upper and burgeoning 'professional' classes of the West established a cosmopolitan lifestyle which spread to the upper classes of the world. It was a time of transcontinental travel, a taste for the exotic and intense flows of information. Newspapers, magazines, pamphlets and book publishing flourished, as did the theatre, opera, museums, galleries and other forms of entertainment. The gradual reduction in working hours – initially fought for by campaigners for social justice and the unions but later used as a hiring incentive by Ford and his imitators – intensified the development of leisure as both a lifestyle and an industry for the twentieth century (Surdam 2015). Cities grew upward: multi-story buildings housed offices, apartments and hotels, lit by electricity and connected by telephone. And while electrification led to the 'hollowing out' of skill distribution in manufacturing in the early twentieth century (Grey 2013), the number of service jobs related to these new ways of living continued to grow.

Thus in each revolution, it has been the demand for new services and supplies around the new way of life that has created massive numbers of new jobs across the economy. In the end, there will be a wide spectrum of productivity levels, from the highest and most high tech to the lower and lowest tech ones, serving a complex set of needs – many of them new – and allowing profits to be made in different proportions across the whole range. But the question of wages and labour's share remains open. For while the majority of analyses in the future-of-work discourse do recognise that the current range of new technologies and new demands are creating new jobs, the concern is that they are the wrong sort because they pay lower wages than the jobs that have been displaced. It is to this issue that we shall now turn.

6. Technology, Productivity and Social Progress

There is no doubt that every technological revolution has destroyed jobs, skills, industries and hence the livelihood of many people and of many regions. And yet, history also shows that shifting lifestyles as well as the leap in urbanisation in each revolution, create new demands and have led to new investment and new jobs. The process has each time benefitted from government policy providing ample support and directionality. But **the underlying process that leads to such progress is the increase in productivity**.

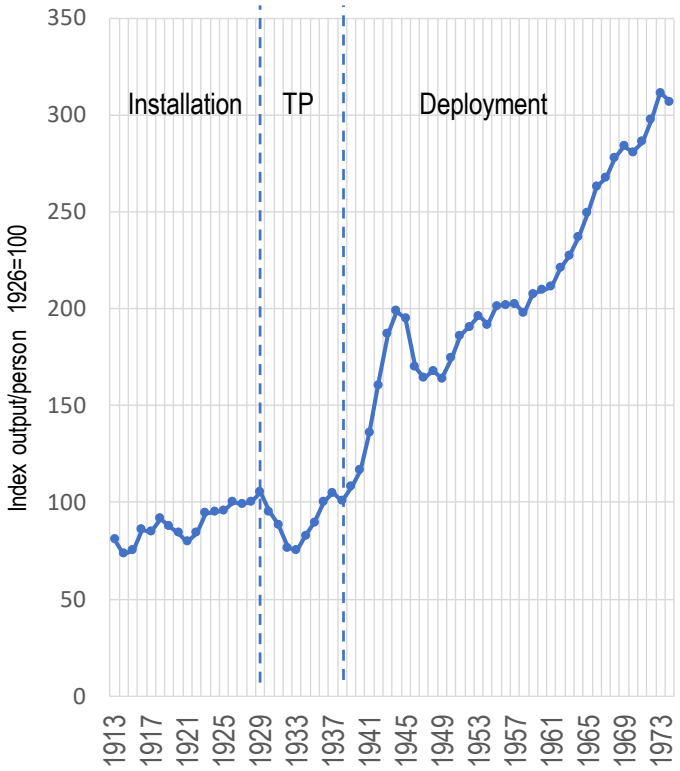
As discussed in section three, historical measurements of productivity are fraught with both practical and conceptual limitations, and the stalling of its growth in recent years has led to a large body of scholarship on (mis)measurement and the difficulty of capturing productivity in the age of intangibles (Byrne et al. 2016; Syverson 2017; Grifell-Tatjé et al. 2018; Goldin et al. 2019).

However, seen from the historical behaviour of technological revolutions, **there are two reasons why the productivity figures do not – and should not – show significant increases in the early decades of each revolution, compared with later ones**. The first is that a radical change of technologies implies a radical change of organisational paradigm. The early decades, or installation period, are characterised by a battle between the inertial forces of the previous paradigm and the disruptive forces of the new, which is struggling to define the best practice forms for the production and business organisations (Bodrožić and Adler 2018). Until these are found and widely adopted, productivity results cannot reach their potential heights. This is likely to explain Solow's oft-cited comment on the failure of the computing age to show up in the productivity statistics (Solow 1987).

A second reason for unimpressive productivity figures in the aggregate is that the process of encompassing the whole economy takes a long time, not only for the resistance just mentioned but due to the lack of directionality on the part of the government. The installation period of the ICT revolution has, in fact, been the longest in history (Perez 2009). It is in the deployment period, which is the later and fuller phase in the adoption of each revolution, that it is adopted across the whole economy and not only in a few vanguard sectors. That is when the real leap in productivity is achieved, and it is an important part of why such periods are called 'golden ages'.

Figure 8 shows how the mass production revolution, even in the investment boom of the 'Roaring Twenties', did not reach the notable increases in productivity achieved from the 1940s to the 1970s. It was then when government procurement for the war, followed by the Welfare State, suburbanisation and the Cold War, led to the high productivity rhythm characteristic of the post-war boom. Without such levels of productivity growth, the so-called golden ages would not be possible.

Figure 8
Evolution of productivity in the diffusion of the mass production revolution
Output/employed person US 1913-1974 (1926=100)



Source: Authors, based on data from Gordon (2016)

6.1 On wages as a socio-political result

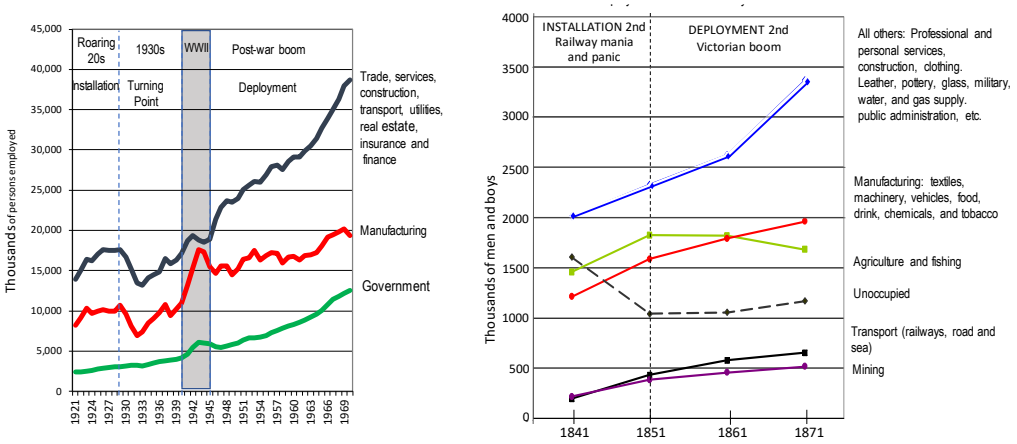
The notion that wages are currently stagnating in the advanced world due to the loss of manufacturing jobs is not based on a historically accurate picture of sectoral employment and wages. It is true that, between globalisation and technical change, many well-paying so-called 'middle income' jobs have disappeared, but as soon as they were exported to Asia, they became low-income jobs. It was not in the nature of the technologies to define the wage level; it was instead the result of socio-political decisions.

Historically, as mentioned above, economies have always had a few sectors with very high productivity compared to the great majority. In fact, up to now, throughout successive industrial revolutions, **manufacturing tended to have the highest productivity levels and the greater investment, while it was services that created the greatest number of jobs**, hence why the changes in lifestyles described above were so important in job creation.

Figure 9 shows that the more mechanised – and therefore higher labour productivity sectors – by definition, had slow employment increases even though growing the fastest. In the case of the US

(figure 9a,) with the productivity leap of the fourth or mass production revolution, manufacturing output was multiplied by three, while jobs barely grew fifty per cent. In that case, **it was the service sector – including the government – that provided the tripling of jobs**. Figure 9b shows a similar pattern for the UK during the second revolution. The growth of cities was very much responsible for the flourishing of service activities, which was also characteristic of the Belle Époque (the deployment period of the third revolution) in the advanced countries.

Figures 9 a & b
(8a) US 1921-1970 evolution of non-agricultural employment by sector
(8b) UK 1841-1871 Evolution of employment of men and boys

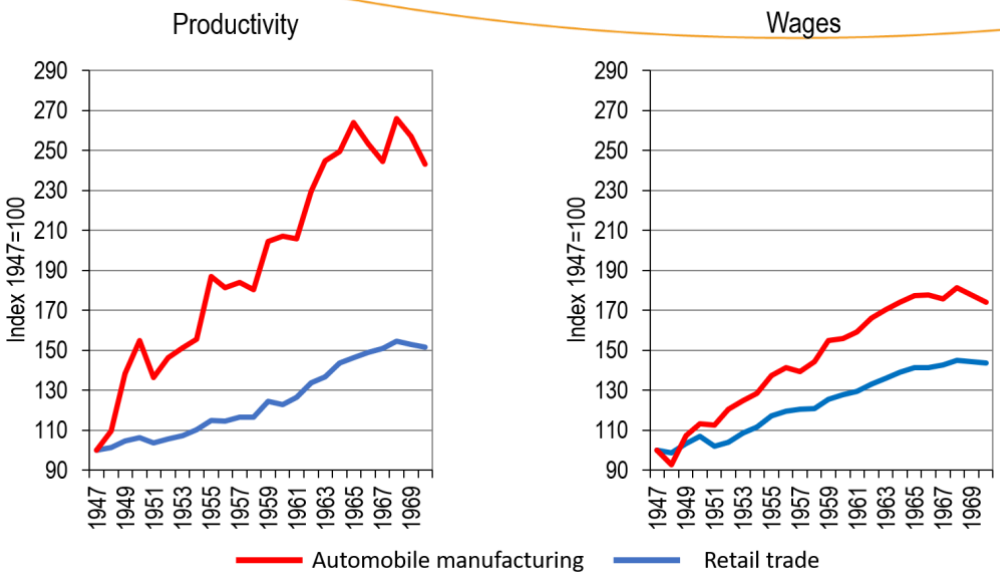


Source: (1) US Department of Commerce (1975); (2) UK Mitchell (1988), Table II-2. Based on the census figures, but with 1911 census categories. Authors' period indications.

In fact, as discussed in section three, the service sector has been the largest sector for jobs during the entire period of industrialisation (Shaw-Taylor and Wrigley 2014; Broadberry et al. 2015). Figure 10 shows that in the US during the golden age, **the difference in wages was much smaller than the difference in productivity between the automobile industry and retail trade**, which allowed both groups to be part of the middle-income consumer class. However, the figure also illustrates how stalling productivity growth in the late 1960s indicates maturity and affected salaries.

Figure 10

Index of productivity and wages in selected industries US 1947-70 (1947=100)



Source: Authors, based on data from US Department of Commerce (1975).

Governments were active on both the supply and the demand side, shaping the growth that made full employment possible. Essentially, **the state gave a clear direction for innovation and investment through a systemic set of policies that encouraged high productivity activities while also creating opportunities for low productivity ones that took up the employment challenge**. As average productivity grew in each society, the wages of the low productivity sectors also increased. This was, of course, favoured by government support of strong unions and collective bargaining.

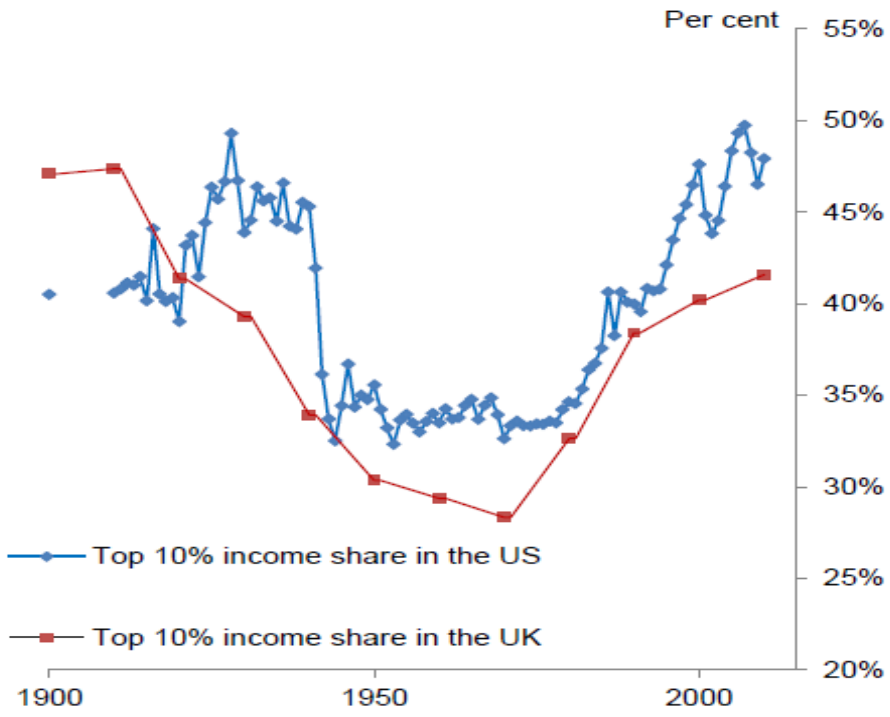
In the case of the US (as shown in figure 10), the post-war experience gives us a glimpse of how **government policy can change the context in such a way that the interests of business and society coincide**. Historically, trade union protests in the US had often been met with violent repression. It all changed when, under Roosevelt, Congress passed the Wagner Act of 1935, which legalised and encouraged their action. Each company wanted the others to raise wages; so the only way to set a fairer and 'level playing field' was to get everybody to do so was to back the unions. Organising by industry of employment, rather than by trades, the new unions facilitated industry-wide collective bargaining, which fitted the non-price competition practices of the oligopolies in the high productivity sectors. **The resulting agreements influenced wages across society so that, rather than widely separating wage levels between high and low productivity sectors, they narrowed the gap**, establishing a relative standard for the whole range, which increased in accordance with the rates set by the unions in the leading industries. This was an adequate institutional set-up to guide markets in a positive-sum direction at a time when national economies were relatively closed. Markets alone would never have achieved it.

6.2. Inequality: from unfettered markets to government action

Notwithstanding this historical pattern, many authors have highlighted the high levels of inequality in the last few decades (Piketty and Saez 2003; Milanovic 2016; Palma 2019). This is interpreted by many of the scholars we have cited to be a direct result of the impact of ICT on the labour market. **Yet the current levels of inequality were there even in the 1980s, when computers were in their infancy, government had not opened up the internet to the private sector, and artificial intelligence looked very limited**. Instead, in those years, the advanced economies were confronting the maturity of the mass production paradigm with various forms of globalisation, stalling wage increases, reducing the workforce and so on. The new millionaires emerging from information technologies and financial manoeuvres were a minority, even in the US economy. What the Thatcher-Reagan 'revolution' did was to dismantle as much as they could of the protective measures provided by the state for the weakest members of society. Consequently, as figure 11 shows, the proportion of income going to the top ten per cent of earners began then climbing from thirty-three to fifty per cent, just as it had done in the 'Roaring Twenties' when the state had also left the market in control. The figure shows only the US and the UK, which are possibly the most acute cases of the general trend. The reduction in inequality shown in the post-war decades occurred when an active government had established regulation and welfare measures.

Figure 11

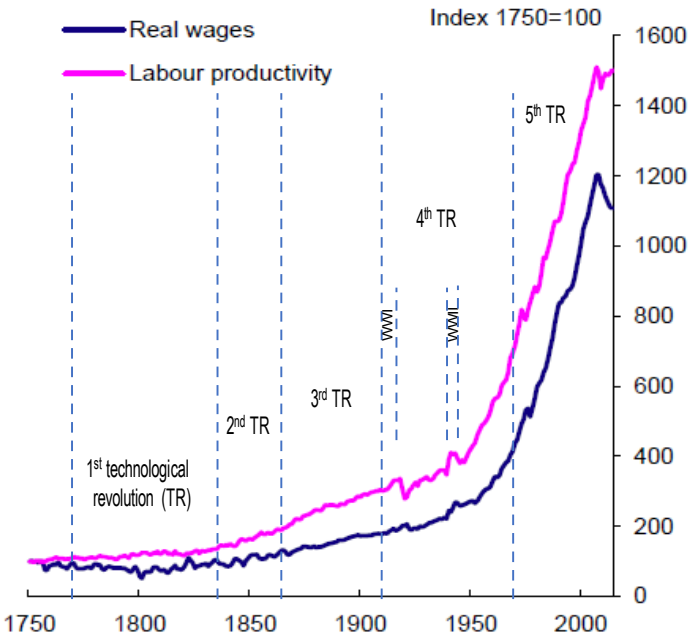
Shares of income going to the top 10% of income tax payers UK and US 1900-2010



Source: Haldane 2015 (from Piketty 2014)

Given the history of inequality, it might be surprising to find that real wages and employment tend to follow the general rhythm of productivity. As we suggested, and as Piketty and Saez (2016) show, the advances are achieved after having gone through difficult periods of increasing inequality, as shown in Figure 11. Figure 12 graphs the path of real wages in the UK, along a similar one for productivity, beginning at the end of the eighteenth century, when capitalism was in its very early beginnings. Both series increase very slowly for the first hundred years, then grow at a brisk pace until the Second World War, when they both take off until the present, after which a slowdown in both indicates what we have been discussing.

Figure 12
Real wages tend to follow productivity
UK since 1750



Source: Haldane (2015) with data from Hill, Thomas and Dinsdale (2015). Authors' periodization.

6.3. Uniqueness and regularity

Piketty and Saez (2016) believe that the improvement in the 1950s and 1960s is an exception in a secular trend. So do Gordon (2016) and Hobsbawm (1994). This is not to deny that it was the best of times for the majorities in the advanced West. Yet better times have come with each revolution. As we have discussed, in every installation period, the creative destruction process eliminates skills and industries, devastates regions and polarises incomes between winners and losers. This has always led to new wealth concentrating in the hands of the novel entrepreneurs and of the bold and ruthless investors and speculators. That is the market working in disruptive mode. But, in every case too, the resulting tensions bring revolt and resentment, giving way to populist leaders, new

movements and divisions in the previously established political parties. All this threatens the system and, in previous transitions, has brought forth political leaders that have responded with the appropriate policies to set up a positive sum game between business and society (or at least with broader layers of society).

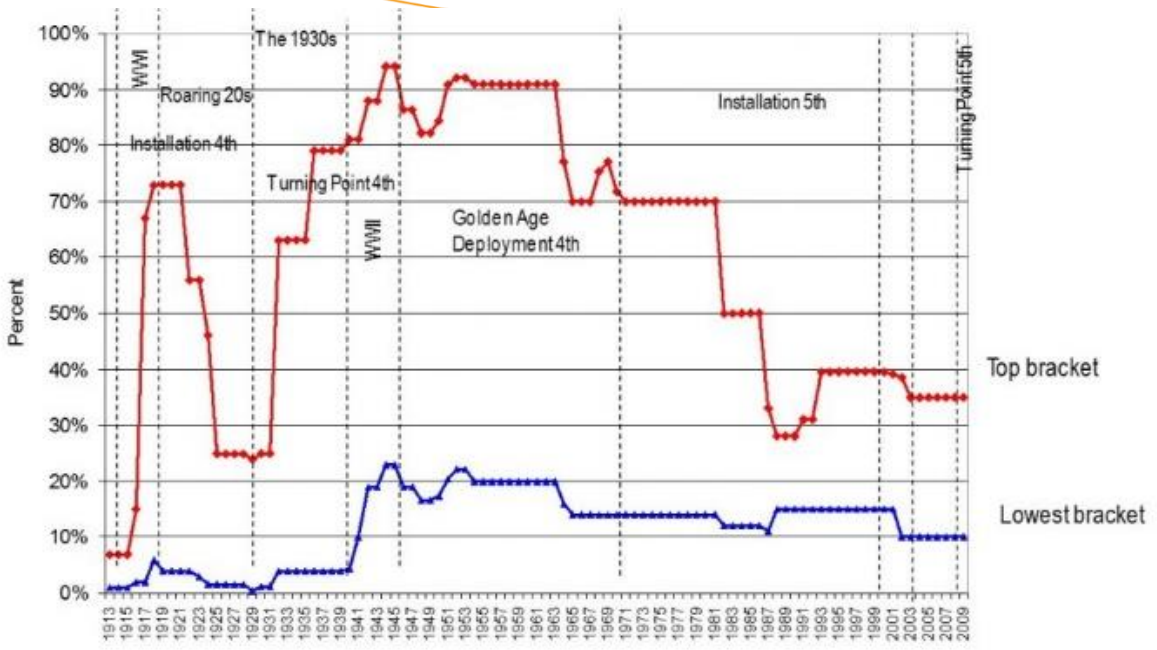
One cannot deny that the existence of the Soviet system offering a vision of worker power was one of the elements that convinced governments and businesses to improve workers' incomes and life conditions. But, even if that had provided the original impulse, the fact is that the resulting growth in mass consumption was a boon for business. At the time, Eisenhower (1964) could observe: 'Should any political party attempt to abolish Social Security, unemployment insurance, and eliminate labor laws and farm programs, you would not hear of that party again in our political history.'

Indeed, it is through a mixture of government regulations and welfare measures imposed for both humanitarian reasons and for the sake of social peace, that the 'creative construction' times, usually seen as golden ages, become socially fairer. It is also, however, through the State providing a synergistic direction that the greatest economic impact is achieved. It is through tilting the playing field through redesigning taxation, regulation and public investment that markets are made to work in 'constructive mode' and, in a context of social redistribution, spread the benefits of each revolution across society.

Even Engels, during the Victorian boom of the second surge, saw a sufficient improvement in the lives of the working classes that he wrote to Marx, warning him not to expect the working classes to rebel because 'the long period of prosperity is bound to have made the masses damned lethargic' (1857:2010, p.203). In the 1900s, the deployment period of the next surge, various social movements encouraged European countries to follow and surpass the German example, implementing what we now see as early version of welfare state measures. Great Britain lagged, until the Liberal Prime Minister Lloyd George in 1909-11 imposed the 'People's Budget', explicitly aimed at tackling the shocking poverty described in reports by Booth and Rowntree between 1901 and 1903. The funding came from an unprecedented tax on wealth. Bismarck had pioneered such measures in Germany as early as the 1880s, and most European countries set up similar social security policies in the 1900s. At the same time, during the Progressive Era (from 1900) in the US, regulations were brought in to protect consumers from health hazards and unjustified high prices as well as shielding the smaller producers from the excess power of trusts and monopolies.

In the case of the last surge, inequality was reversed by government policy in the post-war period – 1950s and 1960s – in what has been the most successful positive-sum game in the history of capitalism. The policies that led to that result seemed as impossible to consider in the 1920s as they would do now. Just to give an idea of the magnitude of the change, we can look at the top and bottom tax rates during that golden age (see figure 13). Such high rates are historically associated with wartime (as was the case in the US in both WWI and WWII) and not with a peaceful and prosperous period.

Figure 13
US income tax spread lowest to highest rate 1913-2009



Source: U.S. Department of the Treasury. Authors' period indications.

In this case, not only does it seem astonishing in today's policy climate that a rate of 90%+ was accepted, but also that it was held steady by Eisenhower, a Republican president. The explanation is simple. As noted, business learnt two crucial things during the war: one, that taxes went through the hands of the government and returned as demand for their products and, two, that, given the new mass production methods, the greater the demand for identical products, the lower the unit cost and the higher the potential profit. **The taxes that turned into massive and uninterrupted demand for the products of the 'American Way of Life' and for the Cold War were the best profit-making opportunity**.

7. Conclusion: The Social Shaping of Technology

The aim of this paper was to reveal the technological determinism underlying debates on the future of work, and to investigate assumptions that what the employment data has revealed as occurring over the last few decades will necessarily continue into the future. We have concurred with the findings of other that each technological revolution, after a period of 'creative destruction' (Schumpeter 1942), has historically seen the creation of a vast range of previously unimagined jobs. However, our emphasis is that these are not solely the result of market forces, nor concentrated in the industries of the new technologies. Rather, these have been in response to the massive shifts in lifestyle that have characterised the propagation of each technological revolution. They have also been created by a proactive state, providing not only infrastructure works and other job-creating activities to facilitate the full deployment of the new industries and technologies but also directionality. This has meant a set of systemic policies that favour the most promising of the trends created by business with the new technologies. Thus, **a coherent set of services from suppliers to transporters and distributors generate employment at the same time as they create synergies in the economy.**

The ICT revolution has destroyed many jobs and, by facilitating globalisation has redistributed employment across the world, hurting workers in the most advanced countries. However, following historical experience, we believe that, given an appropriate direction for innovation and redistribution policies to match the present context, there is still vast job creation potential ahead. We have written elsewhere that the best direction to unleash a golden age is growth that is smart, green, fair and global: already, we see new jobs being created in that direction (Perez and Murray Leach 2018; Perez 2019).

Certainly, the historical record suggests that capitalism has indeed achieved progress for workers, from the original 'satanic mills' to the current situation in the advanced world where workers are expected to have a comfortable life. But it has not been a smooth progression but a ratcheting effect, where some of the gains of one golden age are lost to some of its beneficiaries, which leads to social unrest and a threat to the system, moving politicians to respond and set up a new win-win game with wealth spreading across society (Perez 2002).

Yet, is the current moment different in kind? Given globalisation and the likely reduction of demand for human work due to robotics and artificial intelligence, it might well be. Does the widening and deepening of the squeezed middle indicate that wages will equalise down in a race to the bottom (Frey and Osborne 2013; Brynjolfsson and McAfee 2014; Haldane 2015)? If markets are not steered in the interest of society, if their profits are not somehow linked to the well-being of the citizens of the country, that is indeed a possibility. Frey (2019), again building on the work of Acemoglu and Restrepo, is concerned that this, in turn, will generate protest and a subsequent political reaction that leads to the suppression of new technologies, a modern form of Luddism that will compound the problem by slowing down productivity overall. We are not as convinced that this would be the political response to worker demands. However, we are in agreement that the prosperity from the productivity gains generated by robots and AI must be shared across society, and 'needs the design of new and improved institutions' to do so (Acemoglu and Restrepo 2018, p.33).

Like the new technologies themselves, the ideas for these new and improved institutions develop in niches (Geels 2004). There is no shortage of them at this transitional moment in time. Within the BEYOND4.0 team alone, there are proposals for restructuring the welfare state in order to accommodate new ways of working (Hiilamo 2022) and for cooperative platforms for Big Tech that have the potential to rectify the current issues of remuneration between suppliers and users (Ryan-Collins et al. 2022). However, also like the new technologies themselves, such proposals generate at least as much fear as they do support, and hence meet with considerable resistance. So long as we remain stuck in thinking that it is only the market that can generate both jobs and high wages, the space for such radical measures is slim. But band-aid proposals have never provided the answer, and never will.

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