

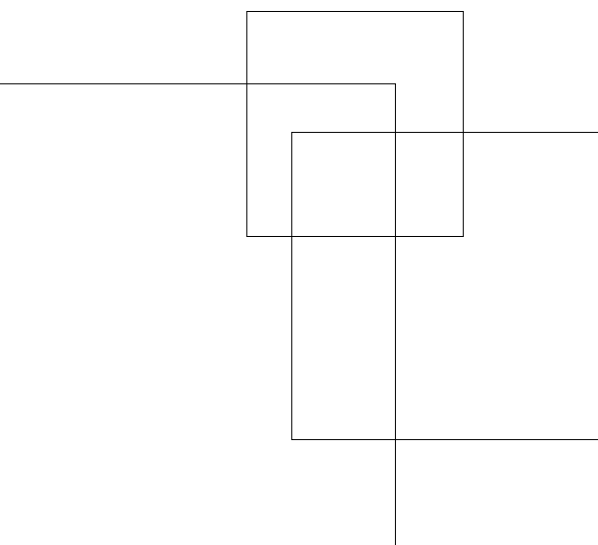


International  
Labour  
Office

RESEARCH DEPARTMENT ||||| WORKING PAPER NO. 13 |||||

# New technologies: A jobless future or golden age of job creation?

IRMGARD NÜBLER |||||



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NOVEMBER 2016

Research Department Working Paper No. 13

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golden age of job creation?**

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November 2016  
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*ILO Cataloguing in Publication Data*

Nübler, Irmgard.

New technologies: a jobless future or golden age of job creation? / Irmgard Nübler; International Labour Office, Research Department. - Geneva: ILO, 2016.

(Research Department working paper; No. 13, ISSN: 2413-4589 (web pdf))

International Labour Office. Research Department.

future of work / technological change / innovation / employment / job creation / job destruction / capabilities / social transformation

13.01.1

## Abstract

The new wave of technological innovation is expected to fundamentally change the future of jobs. The debate on the impact on jobs, however, is controversial. Some expect a jobless future, while others argue that history will repeat itself, and new technologies will eventually create new and better jobs. This research aims at a better understanding of the dynamics of job destruction and job creation. The paper develops a framework to explain the nexus new technology, innovation and job, and the forces driving labour-saving as well as job-creating innovations. Technological change is explained as a non-linear and complex process which comes in waves and different phases, and market, social and political forces are driving the dynamics of job destruction and job creation.

The paper firstly explains the role of market forces in driving automation and fragmentation as two forms of process innovation that destroy jobs in industrial production regimes. Secondly, markets also create jobs by adjusting to increased productivity and jobs losses. However, due to country-specific social capabilities the net impact on jobs differs significantly across countries. Finally, this paper explains the long-term process of moving towards a golden age of job creation. Such a phase of massive job creation can only be achieved by transformative changes in the economy where radically new products and new growth industries emerge in a process of creative destruction. Such changes cannot be generated by markets, they are a social and political choice. The paper argues that unintended consequences of past technological changes have disruptive effects in societies and natural environment which trigger social debates and movements, societal learning processes, and eventually, new social and political demand and new capabilities. It is this social transformation that propels transformative structural changes in the economy and massive job creation.

This paper concludes that technological change and the future of jobs is not deterministic, but needs to be shaped. Both, market adjustment and societal learning processes drive endogenously the job-creation dynamics. The challenge for public policies is to foster the dynamics of societal learning and economic transformation.

## Acknowledgments

The author wishes to thank in particular David Kucera and Uma Rani who reviewed the paper and provided valuable suggestions, Deborah Greenfield for support and encouragement, as well as Ekkehard Ernst, Sangheon Lee, David Seligson and Theo Sparreboom for helpful discussions and comments. Many thanks go to Duncan Campbell and my Research Department colleagues Marva Corley-Coulibaly, Guillaume Delautre, Carla Henry, Dorothea Hoehcker and Catherine Saget who provided useful comments to earlier versions of this paper. Nikita Grabher-Meyer, Laura Nübler and Michael Nübler provided valuable research, data analysis and editing support.

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*The robots will only eat all the jobs if we decide to let them.*  
Lanchester (2015)

## 1. Introduction

Fundamental changes in technologies and production systems and the emergence of new industries are major drivers of growth and development. They have the power to transform the world of work by destroying jobs, generating new ones and transforming the nature of jobs. Hence, ever since the Industrial Revolution, workers, business people, policy makers, and academics have been ambivalent about technological progress. The recent wave of technological change is once more garnering widespread attention and has created a controversial debate on the future of the world of work. Some believe that the new wave of technological change and innovations will destroy jobs at a massive scale, and foresee a jobless future (Ford, 2015; McAfee and Brynjolfsson, 2014; Hawking, 2016). In contrast, optimists are confident that new technologies will mobilise adjustment and transformative processes that will create new jobs, and even “golden ages” of job creation (Perez, 2002; Vivarelli, 2007). This optimism is supported by historical experience. Economic historians show that, while each new wave of technological change has created phases of job destruction and technological anxiety, eventually, new and better jobs were created (Mokyr, Vickers and Ziebarth, 2015; Bessen, 2015).

History, however, does not always repeat itself, and some observers believe that we are currently witnessing a critical departure from the historical pattern of techno-economic change. They highlight the unique and highly disruptive nature of newly emerging technologies and the unprecedented pace of change. The combined effects of multiple new technologies such as multi-functional sensors, learning robotics, the Internet of Things or 3D printing, are expected to be deep, wide in scope and large scale and therefore, to generate unprecedented loss of jobs (Schwab, 2016).

While the future is uncertain, central issues in analysing the impact of new and emerging technologies on jobs in the future are therefore to understand the link between new technologies, innovations and jobs, identify the forces and mechanisms that destroy jobs and those creating jobs, and the linkages and interaction between them.<sup>1</sup> This paper develops a framework to explain the process of jobs destruction and jobs creation by integrating insights from different traditions in economics - evolutionary, structural and market economics. This approach allows to take into account different types of innovations, short-term and long-term as well as revolutionary and evolutionary adjustment processes, the role of economic, social and political forces, and the complex, non-linear and uncertain nature of the process.

While definitions of technological change differ widely, this framework takes a broad approach in order to take into account the different stages and forms of innovation that can potentially affect the quantity and nature of jobs. Technological change is reflected in the discoveries of new scientific and technical principles (inventions), in the commercial ideas of entrepreneurs and their implementation in the economy. An important distinction is made between process innovations and product innovations. While process innovations relate to new production techniques, new organization of work or business

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<sup>1</sup> This paper takes an inductive approach to research as opposed to a deductive approach. The inductive approach explores existing data and analysis, historical observations, regularities and recurrences as well as theories and concepts, and interprets them in the light of this paper’s particular research question. Based on these elements, it develops a framework to explain the process and the various forces that shaped jobs destruction and creation in the past. This framework will be used to analyse the impact of new technologies on the future of jobs.



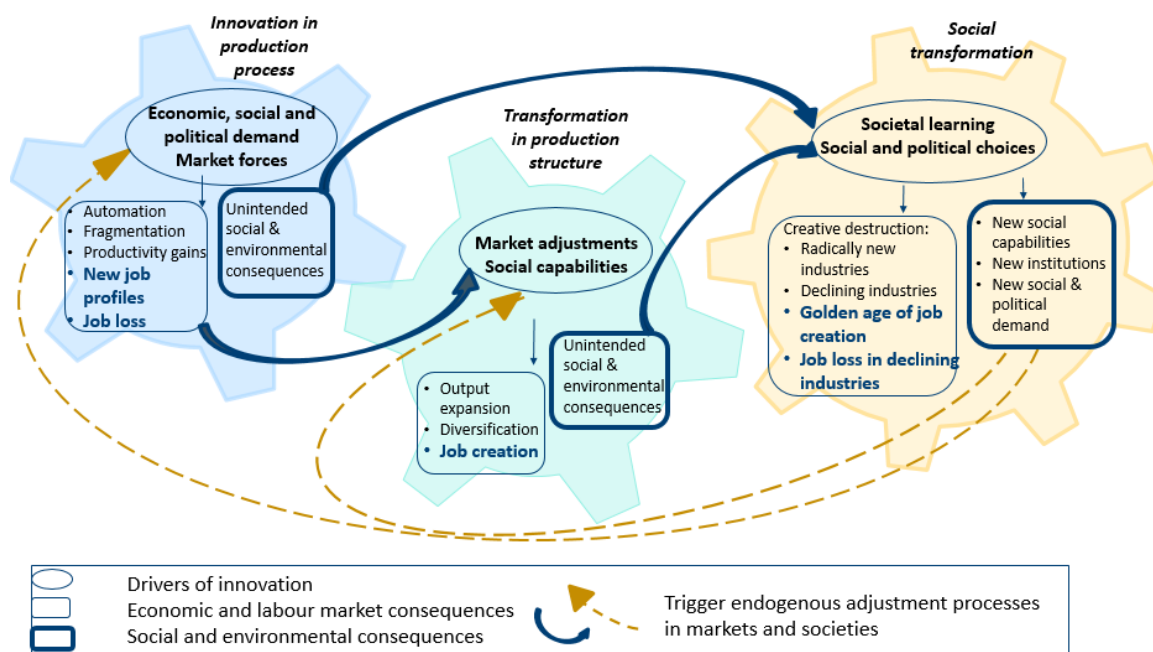
models, product innovation is expressed in product differentiation, the implementation of significantly improved products and the development of fundamentally new products, industries and sectors.

The distinction between process and product innovations may not always be clear-cut, and some product innovations such as capital and investment goods become process innovations at a later stage of the economic cycle. However, structural and evolutionary economists argue that the analytical distinction is necessary to make possible the study of the relations between the two. Mainstream economic theory tends to assume that all innovations are forms of process innovation (reflected in higher productivity), and therefore ignores product innovations as a main mechanism behind structural economic change, job creation and reducing unemployment (Dosi, 1982; Lundvall, 1985; Vivarelli, 1995).

In assessing the impact of new technologies and innovations on jobs, it is important to also define the meaning of a job. While there are various ways, the ILO (1990) defines a job as “a set of tasks and duties, performed, or meant to be performed, by one person, including for an employer or in self-employment”. This definition allows to describe a job by the scope, nature and profiles of tasks, and to analyse the impact of innovations on job loss, job creation and changes in the task profiles. Similar and related jobs can be grouped into occupations which the ILO (1990) defines as a “set of jobs whose main tasks and duties are characterised by a high degree of similarity.”

Figure 1 presents the framework elaborated in this paper. The dynamics of job destruction and job creation is driven by innovation in production processes (blue colour), transformation in production structures (green colour) and social transformation (yellow colour).

Figure 1: The dynamics of job destruction and job creation in a context of technological, economic and social transformation



*Note:* Each of the three dimensions of the job destruction and job creation process (the three gear wheels) drives innovation through distinct forces, creates different forms of innovation in economies, with particular intended and unintended consequences in labour markets as well as in social and natural environment. Most importantly, these consequences trigger endogenous adjustment processes that create new waves and phases of technological change and innovation (depicted by the various arrows). In this sense, process, product and social innovations are part of a continuous process that shape the future of work.

The paper is organised into four chapters. The following two chapters focus on market forces as the drivers of job destruction and job creation. While chapter 2 (blue wheel) discusses job-destroying process innovations, chapter 3 (green wheel) explains the creation of new jobs as a result of adjustment mechanisms, social capabilities and product innovations. Chapter 4 (yellow wheel) analyses the long-term dynamics of job destruction and job creation. It explains the transition into a golden age of job creation as a process of social transformation which creates new social and political demand, mobilises new social capabilities and supports a transformative process of creative destruction. Finally, the paper provides conclusions.

## 2. Job destruction – The quest for productivity

One of the major long term trends observed empirically is the evolution of labour-saving technological change. The job-destroying nature of technological change is mainly embodied in process innovations. Such new technologies, however, are not “falling from heaven” – the assumption of traditional economic growth models (Solow, 1956). Technological change is largely the result of deliberate search of firms, entrepreneurs, workers, scientists and engineers to solve problems and respond to economic, social and political demand. The nature of technological change is therefore shaped by local conditions such as resource endowment, geography, institutions, preferences, needs and demand. “They determine what kind of inventions, product characteristics and factor-saving biases will be profitable to develop and exploit” (Rosenberg, 1993).

This section explains the forces driving the long-term trend of job destruction. It identifies the quest for productivity as a major driver of technological change, and argues that since the Industrial Revolution and the introduction of the industrial production mode, process innovations drive productivity by enhancing labour-saving technological process innovations. This implies that the innovation behaviour during the pre-industrial production mode was very different, and that production modes may emerge in the future that follow different principles and drive a different nature of technological change.

During the pre-industrial era, work has been organised in the crafts production mode where craftspeople were producing customized and tailor-made products for particular clients. Crafts people therefore largely competed in technical expertise, problem-solving competences and creativity. Work was organised in workshops with limited division of labour. Technological innovations in the craft sector aimed at augmenting the competences of crafts people and improve their work procedures and material, but they did not aim at replacing workers. Studies show that the traditional guilds-based system provided an institutional framework that ensured high quality vocational training in apprenticeship systems, which is considered as a major source of technological inventions and innovations in the traditional crafts sectors (Epstein, 2008; Sennett, 2008).

A major innovation introduced by the Industrial Revolution was the fundamentally different organization of the production process. The industrial production mode was shifting production from workshops to factories, from customised to standardized products, and production for a specific client to production for the market. While firms in the crafts production mode were competing in competences and “craftsmanship”, firms in the industrial production mode began to compete in prices, costs and quality of standardized products. Competition and market forces intensified the pressure to increase productivity, and to search for technological knowledge and process innovations that can produce products at lower costs or at a higher quality at given costs.

Moreover, history shows that institutions have played an important role in promoting the industrial production mode and intensifying competition in markets as a means to promote productivity growth.

These changes in institutions were the result of new social and political demand. For example, the rapid population growth during the 18<sup>th</sup> and 19<sup>th</sup> century in European countries increased demand for food and clothing, and the pressure to increase productivity in agriculture and textile. New social and political demand for liberalisation triggered institutional changes that promoted the establishment of factories outside of the restrictive medieval guilds system, fostered R&D and the wide diffusion of innovations. A more recent example is provided by the new institutional framework established by the WTO to regulate international trade and promote competition in international markets in order to generate productivity gains. A growing political demand for “level playing field”, efficiency and economic growth since the 1980s triggered labour-saving process innovations in industrialised countries.

Since the Industrial Revolution, the continuous quest for higher productivity has generated automation and fragmentation of production processes as two long-term trends in technological change. These two forms of process innovations increase productivity and competitiveness by saving labour and destroying jobs. Automation and fragmentation need to be analysed together as part of a framework that aims at explaining the impact of new technologies on the future of jobs.

## **2.1 Automation and robots**

A major feature of the industrial production mode is the standardization of products and production processes. Standardisation allows for the routinization of work procedures and automation of tasks. Machines substitute tasks performed by workers by encoding standardized procedures in algorithms which can be performed by machines. Automation lowers costs, reduces human error and enhances quality. Since the Industrial Revolution, we observe different waves of automation with each wave destroying jobs as well as increasing complexity of task profiles of jobs and occupations.

### *Substituting, complementing and augmenting human tasks*

The definition of jobs as a set of distinct tasks allows to describe a job by the nature of its tasks, and to assess the impact of automation on tasks rather than jobs. Autor, Levy and Murnane (2003) distinguish between manual and cognitive, routine and non-routine tasks. Studies using this classification show that automation has initially replaced manual routine tasks, then manual non-routine tasks and increasingly also cognitive routines and non-routine tasks. Jobs with narrow task profiles and low complexity were often fully replaced. In contrast, jobs spanning a wider range of different tasks and higher complexity are more resilient. Machines and robots tend to complement part of these tasks, and they augment performance of those tasks that were not automated.

At the early industrial stages, mechanisation, for example of spinning and weaving, replaced repetitive manual routine jobs which could be performed by new tools and machines. Since the 1960s, industrial robots and software to control machine tools in manufacturing replaced heavy, dirty and risky jobs, while the nature of jobs at the machine/human interface changed and became more complex. This was the case with computer-aided manufacturing (CAM) and computer-aided design (CAD), e.g. in the car industry or in chemical and basic metal industries (Autor, Levy and Murnane, 2003; Balconi, Pozzali and Viale, 2007). The introduction of microprocessors in the early 1970s generated a new wave of process innovations based on digitisation. Digitized algorithms and increasingly powerful microprocessors could simulate not only manual routine, but also manual non-routine work, and increasingly also cognitive routine tasks. Since the 1980s, computers therefore took on the precise executing of repetitive physical operations, tasks of book-keepers and clerical staff, as well as cognitive “routine tasks” of mathematical calculations, retrieving, sorting, and storing of structured information.

Workers increasingly focused on executing the non-routine tasks which require flexibility, creativity, problem-solving capabilities and complex communication skills (Autor, Levy and Murnane, 2003).

A new wave of mobile, autonomous and learning robots is combining multiple new technologies: They use advanced sensor technology to collect big data sets at high speed and laser, infrared and ultrasonic sensors to avoid collisions of mobile and humanoid robots, as well as innovative imaging technologies to generate pictures, graphs and movies. Ubiquitous broadband and software development capacities, complex and optimizing algorithms; exponentially growing data processing capacities and feedback mechanisms in software enable self-improving, learning and artificial intelligence.

Mobile robots can perform a variety of tasks, as opposed to the highly repetitive tasks performed by large, industrial robots used in assembly lines. While large industrial robots have replaced entire jobs in the past, the newly developed mobile robots tend to complement human tasks. In manufacturing, the mobile robots support small and medium-sized firms in specialized tasks or niche markets. Mobile robots will not replace skilled workers, but collaborate with workers, and complement the non-routine cognitive, interactive jobs performed by workers. One example is the YuMi (you and me) robot of ABB which performs a variety of precision tasks.

### *The future of automation: customization and smart mass production systems*

The use of machines, robots and computers in the production process is expected to diffuse widely into all sectors of the economy. Artificial intelligence, humanoid, mobile and collaborative robots will be further developed and used in small and large firms. This development will continue to replace and transform jobs, however, at the same time there may be limits to automation.

A newly emerging trend is the increasing demand of consumers for customised, tailor-made and individualised products. Such trends are reflected, among others, in the growth of the craft and artisan economy or in the rising demand for luxury goods, e.g. in the high price segments of car, watch, or textile industries. Large firms respond to this growing demand for customisation by developing a “hybrid” production process of “customised” mass production. Mobile robots are used to perform a variety of tasks as opposed to the large, industrial robots which perform the same tasks repeatedly (Winfrey, 2014). Low-cost collaborative robots are a boon to small and medium-sized companies that compete with firms from low-cost markets. Collaborative robots augment human tasks, and allow workers to increase productivity by focusing on the more sophisticated non-routine tasks.

For example, Mercedes factories are replacing heavy industrial robots by smaller and flexible robots (e.g. producing the Class S 2018, the most expensive model), and BMW and Audi are testing lightweight, sensor-equipped robots to respond to the demand for individualised cars. Since “the flexibility and dexterity of human workers is reclaiming space on Mercedes’ assembly lines”, new and more sophisticated jobs in middle occupations are created (Behrwald and Rauwald, 2016).

Second, automation will enhance sophistication of mass production systems in industry, agriculture and the service sector. Such systems are enabled by the Internet of Things (IoT) whose advantage lies in the low costs to generate, transfer and analyse high quantities of data, which firms can collect in real-time and communicate to a network of computers for analysis and coordination of activities and flow of goods, cash and information. In manufacturing, many countries launched initiatives to develop Industry 4.0 in Germany, advanced manufacturing in the US or Usine/Industrie de la Future in France. The goal is to increase productivity by automating the full value chain in manufacturing and integrating autonomous robots and computers into a data network that connects companies, departments, and functions.

Also commercial agriculture is using the new technologies to create production systems that enhance productivity due to global competition and a growing global population. “Smart” farming uses computers to control the production process and optimize the inputs and conditions for reliable and standardized products such as crop, meat or fish. For example, moisture sensors planted in the soil send their information to a computer network for analysis, which in turn will send the results back to the farm’s irrigation systems to ensure the optimal and precise sprinkling of each tree with water and nutrition content (The Economist, 2016).

Finally, the service sector applies increasingly the new sensor and Big Data technologies. By standardising tasks, pre-defining procedure and time schedule, and monitoring performance of workers in real time, the provision of services can be optimised and fine-tuned. For example, cars of technicians may carry sensors to document the routes they take in providing services to customers and the time they spent at one place which allows to monitor and optimise the service provided (Degryse, 2016).

The diffusion of increasingly integrated production systems is expected to destroy jobs in logistics, coordination and communication, but also in production tasks, and to enhance complexity of task profiles in particular of technicians, managers and professionals. New occupations will be created particularly at the intersection of professions, software and machines. These are often “hybrid” occupations combining skills and competences from different domains, e.g. big data architects and analysts, cloud services specialists, digital marketing professionals, legal knowledge engineers or process analysts (Susskind and Susskind, 2015; Frey, 2014). The task of managers will transform as learning and connected machines will support all manners of day-to-day management decisions, and take over routine decisions of management. Managers will frame the questions which computers have to answer and they will respond to exceptional circumstances, and determine targets and risk levels to be reflected in the algorithms of machines. Also, work in research, development, and design will change as research becomes more experimental. Big data, digital modelling and simulation make experiments less expensive, and research processes will increasingly be structured around “design-build-test” cycles (Thomas, Kass and Davarzani, 2014; Dewhurst and Willmott, 2014).

A variety of efforts have been made to estimate the potential magnitude of job destruction in the future. For example, Frey and Osborne (2013) explored the potential automation of occupations, that is, the technical easiness or feasibility of computerizing occupations. They estimated that 47 per cent of total US employment is technically in a high risk category “over the next decade or two” and that “occupations mainly consisting of tasks following well-defined procedures and that can easily be performed by algorithms” are susceptible to computerisation. The comparable estimate for the UK is 35 per cent, and studies for Germany and France produced similar results. An ILO study has recently produced a much higher estimate for ASEAN countries: about three in five jobs face “a high risk of automation” (Chang and Hyunh, 2016), thus raising important questions about regional variations in job destruction.

Critics, however, take into account the nature of new robots. They argue that future automation is unlikely to destroy complete occupations; rather, jobs within occupations will vary, and while some jobs and tasks may disappear, others will only change (Autor and Handel, 2013). Studies analysing jobs rather than occupations find significant lower risks for job losses. Arntz, Gregory and Zierahn (2016) find that automation will replace some tasks which will fundamentally change the nature of jobs workers will perform, but the jobs themselves are not at risk. They conclude that in OECD countries on average about 9 per cent of jobs are at high risk of being automated, ranging from 12 per cent in Austria, Germany and Spain to around 6 per cent or less in Finland and Estonia.



Furthermore, the concept of personal or procedural knowledge suggests limits to automation, at least with existing methodologies. The intelligent performance of a task is based on procedural knowledge which a person develops through practice and experience. Such procedural knowledge exists at the sub-conscious level of the brain and it cannot be articulated. This knowledge, however, is expressed in the physical performance of tasks (Polanyi, 1958). In the past, engineers and software developers automated tasks by simulating the bodily performance of a person. They imitated the physical sequence of actions of a person and translated them into algorithms so that they could be performed by machines. The execution of pure cognitive tasks, however, is not expressed in any physical action and therefore, software experts can neither understand the rules nor develop the algorithms that are needed for machines to simulate the intellectual procedures. As demand for customised goods and services is expected to increase, and artificial intelligence diffuses more widely, the share of pure intellectual and cognitive tasks in jobs such as problem solving, interactive and interpersonal competences of jobs increases. Craftspeople and professionals need to execute jobs with increasing shares of intellectual tacit knowledge. As a consequence, the scope for automating tasks is expected to decline in the near future.

The same is true for socially acquired competences that people learn in a process of socialisation during childhood. Boyd and Richardson (1985) argue that individuals acquire socially held values and behaviour in a form on “non-genetic” inheritance, e.g. ethical behaviour, sense of humour, justice or fairness. These values and skills reside in the “mental models” of people, they shape behaviour and choices, and they differ across people from different communities and societies. The mental models and procedural knowledge underpinning such competences can neither be observed nor easily be automated.

## 2.2 Fragmentation of production processes

The fragmentation of production processes is another form of process innovation that destroys jobs. Fragmentation is achieved by dividing the process into different tasks to be performed by different workers, firms or countries. This long-term trend of expanding and deepening fragmentation of production systems has enhanced efficiency through economies of specialization and agglomeration, but it has the potential to destroy jobs.

### *Division of tasks, efficiency and job loss*

Historical analysis shows that the fragmentation of production processes started first by specialization of workers, followed by specialization of firms in particular tasks, and the most recent wave by the division of tasks across countries and geographical space. At the early stages of industrialization, factories divided the jobs that had been performed by one skilled crafts person. Each worker was performing a limited sequence of tasks and productivity increased due to higher dexterity and speed, as well as limited time needed to shift between tasks. Some classical economists as well as some mechanical engineers such as Charles Babbage (1832) were proponents of division of labour, because of the large amount of labour saved by giving workers specialized tasks in Industrial Revolution-era factories (Rosenberg, 1993). It also changed the skills structure of the labour force. Production workers required a limited set of specific knowledge and skills, demand for broadly skilled crafts people declined, while demand for management and coordination skills increased. A new boost of division of tasks was triggered at the beginning of the 20<sup>th</sup> century by the so-called Taylorism. Based on time and motion studies, cost accounting, tool and work station design, jobs were designed with the aim to minimize skill requirements and learning time, and to achieve optimal job performance.

Increasing complexity of production technologies and market expansion, in combination with declining transaction costs of “using the market”, motivated firms to deepen specialization (Coase, 1937). Several factories, each with its own specialization, were processing inputs such as raw materials and producing parts and finished goods. It allowed firms to benefit from economies of agglomeration and specialization.

A new wave of fragmentation was triggered during the 1980s when tasks were relocated across countries, and regional and global supply chains were established. Vertical specialization of enterprises in global supply chains, outsourcing and offshoring of labour intensive production tasks, back office business services and call centres have been exploiting the comparative advantages of different locations in different parts of the world. Developed economies have specialized in high-skilled tasks such as R&D, design, finance and after-sales services, while developing countries have attracted many of the low-wage and low-skilled jobs which could not yet be automated.

This long-term trend of fragmenting production processes – division of tasks between workers, firms, and economies - was supported by major innovations in transport, information and communication systems. Declining costs of trade provided incentives to expand the geographical space for trade. Moreover, new institutions decreased transaction costs such as costs of negotiating and enforcing contracts and coordinating activities, which increase with the level of fragmentation. Since the Industrial Revolution, custom unions, trade agreements and free trade regimes, the harmonisation of regulations across countries (e.g. European Union), and the adoption of regulatory frameworks at the global level (e.g. the rules provided by the WTO) were important institutions to reduce transaction costs and to expand the space for fragmentation.

### *The future of fragmentation: a new pattern of specialization in tasks*

High competition in global markets is expected to continue to drive fragmentation of production processes. The new wave of specialization, however, is expected to be driven more by the service sector than by manufacturing. On the one hand, the potential for future fragmentation in manufacturing is limited because many industries and the specific technologies show low divisibility or fragmentability (Lall, Albaladejo, Zhang, 2004). While the transport vehicle industry, the electrical and electronics sectors, as well as the apparel sector demonstrated high divisibility and have developed significant regional and global value chains (GVCs), capital-intensive process technologies, e.g. in chemical and pharmaceutical industries, demonstrated limited possibilities of separating production segments and placing them at different locations.

Moreover, new production technologies such as Internet of Things and Industry 4.0 are expected to in-source jobs and disrupt value chains. These technologies reverse factor intensities to an extent that developing countries will lose comparative advantages in labour intensive technologies despite low wages. For example, new robots can perform sewing tasks which so far had been remained a job for “nimble fingers” in low wage countries (The Economist, 2015). While the potential for in-sourcing is still limited due to high investment costs and technical challenges, these technologies are expected to diffuse with declining prices for robots, rise of the “hidden” transaction and transport costs (e.g. cyber security, political risks) and political pressure to bring jobs “back home”.

Since the economic crisis, and due to rising political demand for protection of jobs, governments in many developed countries are formulating and implementing technology and industrial policies. The aim is to support R&D and investment in advanced manufacturing that bring back the industrial jobs that had been outsourced to low income countries. This trend is supported by short fashion cycles which require firms to rapidly respond to new fashion trends. For example, Adidas, a global player in

production of sports equipment and sportswear, is currently constructing a new factory in Germany close to its headquarter. This factory will use robots and novel production techniques such as additive manufacturing (known as 3D printing) to produce trainers and other sports shoes—an industry that has been offshored largely to China, Indonesia and Vietnam. Since people want fashionable shoes immediately, and supply chains struggle to keep up, this “Speedyfactory” will shorten this cycle. “By bringing production home, this factory is out to reinvent an industry” (The Economist, 2017).

On the other hand, the spill over of digital technologies to the service sector, the development of powerful algorithms and learning software and the global diffusion of digital ICT infrastructure in emerging and developing countries is expected to enhance the relevance of services in global trade and global supply chains. Digital technologies provide the opportunities for businesses to decompose the jobs of professionals, digitise tasks and relocate service jobs from developed to developing countries. Brown and Lauder (2013) foresee a process of modularisation and “digital taylorism” of back office services. Enterprises will divide office services into specialized tasks similar to Taylorism in manufacturing. These tasks will be outsourced to developing countries which demonstrate growing numbers of highly skilled workers, but wages one third of those in developed countries. The authors see high potential for outsourcing of even complex service tasks.

Moreover, the global spread of the internet enables new business models based on cloud sourcing and computer sourcing. Digital information technologies allow the transfer of large data sets at low costs while internet platforms simulate global market places where demand can meet the supply of service tasks. Cloud sourcing allows firms to access global labour markets in search of specialists and experts. In addition, firms increasingly use cloud computing to outsource IT tasks to specialized providers of IT services which allows them to focus on their core tasks. This helps smaller companies to reduce costs, compete, and create jobs, and to reduce barriers of entry for potential entrepreneurs who have technical expertise in a particular domain, but not in ICT (Institute for the Future, 2014).

Finally, empirical evidence shows that GVCs-related service jobs are increasing. Timmer, Los and De Vries (2015) provide evidence for European countries of the rise in the share of GVCs-related workers providing services tasks to the production of manufactures. A recent study by the ILO confirms this finding. Kizu, Kühn and Viegelhan (2016) show that the importance of service tasks in manufacturing production is rising and has led to a boom in service-sector jobs in global supply chains. The number of jobs related to the “servicification of manufacturing” has been growing much faster than the total number of jobs in global supply chains, largely as a result of increasing sophistication of products and production processes. Both, developed and emerging countries were benefitting from this trend.

The analysis of the future of fragmentation suggests fundamental changes in specialization within global production networks. The new wave of fragmentation will focus on services, and is expected to relocate tasks between developed, emerging and developing countries. Emerging countries are increasingly expected to attract from developed countries jobs in services and the more complex and advanced service tasks such as R&D, marketing or finance. At the same time, emerging countries are expected to foster regional production systems and regional value chains sub-contracting production and assembling tasks to lower income countries (South-South cooperation). Smart manufacturing technologies established in developed countries will re-shore production tasks from low income countries, destroy a significant amount of low skilled jobs, but create few manufacturing jobs in developed countries.

To sum up, this section explains that the demand for productivity growth in an industrial production mode is achieved by process innovations that are labour-saving and therefore job-destroying. Firms



produce standardized products, they compete in prices and quality, and increase competitiveness by enhancing productivity through process innovations. Institutions influence the level of competition and therefore, the demand for productivity increase and the pressure to search for new process technologies. The new waves of automation and fragmentation are expected to replace and relocate in particular service tasks, and to increase complexity of jobs which survive. At the same time, automation and fragmentation are expected to face technical and economic limits.

### **3. Creating jobs – Market adjustment and social capabilities**

While productivity-enhancing process innovations destroy jobs, the important issue is whether new technologies are leading to persistent technological unemployment. Historical experience shows that phases of job destruction were followed by phases of job creation. This implies that the effects of new technologies on productivity and jobs triggered adjustment processes which created new jobs. This section explains the adjustment process by drawing on insights from mainstream economics which focuses on self-adjustment in existing markets, and from structural and evolutionary economics which highlight product innovations, changes in production structures, and the role of capabilities in shaping these structures. Since countries may differ significantly in their capabilities, also the impact of technological change on structural change and net job losses is expected to differ across countries.

#### **3.1 Expansion and diversification of production**

Economists describe various channels through which process innovation can trigger adjustment in labour markets and create new jobs as a response to technology-induced jobs loss (Calvino and Virgillito, 2016; Vivarelli, 2007). Process innovations destroy jobs and increase productivity which create market disequilibria and mobilise market forces (price system, or the “invisible hand”) to adjust the economic system to a new market equilibrium where demand meets supply and full-employment will be established. This model is based on the assumptions that productivity gains are distributed to the owners of production factors and shares between consumers and producers. These assumptions ensure that productivity gains increase demand and investment levels. Higher wages, income and purchasing power, and lower prices increase demand while higher profit stimulates investment and this leads to further productivity gains and scale economies. These effects expand markets and output and they have the potential to compensate for at least part of the loss of employment induced by process innovations (Vivarelli, 2007). The potential to generate jobs in domestic markets by expanding output in existing goods, however, is limited even when demand elasticities are high. This suggests that countries need also to attract foreign demand in order to drive job creation and employment growth.

Development, structuralist and neo-Schumpeterian economists argue that product innovation, diversification and structural transformation are the main drivers of job creation (Ocampo, 2014; Astorga, Cimoli and Porcile, 2014; Lee, 2013; Vivarelli, 1995). Hence, while the expansion effects may compensate for job losses in the short term, job creation in the medium term requires the development of new products and even industries. Historical evidence shows that new technologies destroyed jobs, but they always created new jobs by driving the development of new activities, generating new products and new industries. These product innovations were triggered endogenously by the effects of the process innovation. New jobs were created in the consumer and capital goods industry, in infrastructure as well as in service-based industries.

First, declining working hours and increasing income have led to growing demand for leisure related activities, which had created a wide range of product innovations, entire new leisure industries and

services, and the creation of new jobs. Sports, health, recreation, tourism, music, TVs, computer games, restaurants, fairs and museums, and the do-it-yourself movement starting in the 1980s. The leisure industries have become increasingly technology intensive, and hence, the jobs more complex and skill-intensive (Poser, 2011). For example, the development of increasingly user-friendly camera technologies provided the ground for the spread of photography as a mass leisure activity: the celluloid-based roll film in the 1880s (Eastwood), low-cost and light weighted film-loaded camera; cheaper, easy-to-use cameras with automatic exposure in the 1970s, and the recent digital camera technologies now embodied in smart phones (Poser, 2011). Also amusement parks with ever faster and complex rides, cinemas until the 1960s, and later TVs and the internet became major means of leisure activities. Rising wages since the 1950s and a growing number of vacation days led to a substantial expansion of tourist travel. Since the 1980s the leisure industry has been expanding into sportive activities, which has triggered entire new industries competing in increasingly high technology products and in designs.

Second, the same process innovations which displace workers in the user industries create demand for workers in the producer industries. While the diffusion of combustion engines, of electrical machines and micro-processors has destroyed jobs, many countries saw the rise of a machinery, electrical and electronics, software and computer industry. Also the new robots and learning machines need to be developed, designed, built, maintained and repaired. Moreover, the rise of digital technologies require software and the development of algorithms. The Internet of Things and the collection and commercial use of Big Data will require fundamentally new software development activities, as well as major activities in research and development. These new activities in the R&D and capital industries have high potential to create new jobs and occupations.

Third, the diffusion of automation in service-based industries triggered the development of new products within the industry in order to maintain customer relationship. Automation of tasks in services reduces costs, but it also cuts the personal interaction with clients which tends to be a major factor for building trust and attracting new clients. Enterprises therefore develop new types of services as part of their business strategy which create new jobs and absorb workers whose jobs were at risk. For instance, Bessen (2015) provides the example of automated teller machines (ATMs) which were first installed in the United States in the 1970s. While the number of ATMs increased rapidly, with about 400,000 ATMs installed today, the number of bank tellers did not decrease. The ATMs reduced labour demand for tellers but this was offset by large expansions in the number of branches. The new business model increased branches in urban areas by 43 percent, to develop personal bank-customer relationships.

Fourth, the diffusion of many innovations require the construction and expansion of infrastructure and physical networks. Process innovations in the energy, transport, communication and information sectors requires the development of fundamentally new infrastructure networks. Throughout the past two centuries, canals, railroads, highways, electricity grids, telephone landlines, and more recently, broadband cables and cellular stations were critical for diffusion of productivity enhancing innovations. Also the construction of networks required for high quality Internet of Things, electrical cars, crowd and computed sourcing will once more generate jobs.

Finally, new scientific knowledge that has led to process innovations can also provide “exploitable opportunities” for the development of new products. Creative entrepreneurs design and develop fundamentally new goods and services, develop new business models and create new jobs. For example, the Industrial Internet of Things (IIoT) and Big Data have created a new business model – the manufacturing-cum-service. Firms increasingly combine manufacturing with the collection of data which they use to develop new services. Michelin has developed tires with sensors to collect

information on road conditions, temperature and speed, which provides the opportunity to provide services to truck fleet managers in order to reduce fuel consumption and costs (Daugherty et al., 2014).

### 3.2 Capabilities for product innovation and jobs creation

The historical experience from different places and time shows that structural change and product differentiation were central drivers of job-creating adjustment processes. This perspective raises two distinct issues. Firstly, we need to understand the link between structural change in production structures and changes in employment. Industries differ in innovation activities, and the quantity and nature of jobs that can be created. In other words, the pattern of structural change generated in the adjustment process determines the impact on employment levels as well as on employment structures which is reflected in changing skills, occupations or sectoral employment shares. Secondly, we need to understand the factors that shape the patterns of product innovation and structural transformation.

Mainstream economics is focusing on economic conditions as important determinants of the nature and scope of innovation and job creation. Countries differ in productive capacity, that is, in the factor endowment, industrial structure and comparative advantages which determine cost structures and therefore which technologies and products are profitable. Market forces, however, cannot explain the shift of enterprises and the labour force into new products which are not yet part of the economy's production portfolio. The question is what enables countries to produce goods and services which they did not produce so far, and in which they have no experience. Structuralist and evolutionary economics introduced the concepts of dynamic, technological or social capabilities or productive powers to explain why some countries were more successful than others in generating a process of industrialisation (List, 1841), diversification (Penrose, 1959), catching up (Abramovitz, 1986), development (Lall, 1992) or structural transformation (Chang, 2010; Cimoli et al., 2009).

Based on the various strands of the literature, and different dimensions and concepts discussed, the ILO developed a theory of capabilities for productive transformation in order to explain what capabilities are, where they reside, how they are created, and how they shape structural and technological change (Nübler, 2014b). The theory distinguishes between the physical and the knowledge (intangible) sphere of the economy. While productive capacities are embodied in the physical sphere of production factors and infrastructure (the focus of mainstream economics), capabilities for innovation are embodied in the knowledge base of a society. It is important to understand that capabilities for innovation are embodied in collective forms of knowledge at the level of societies (or social groups like the team of an enterprise), not at the level of an individual.

This theory suggests that social capabilities play two important roles in a country's techno-economic development process. First, they determine the products and industries which a country can easily and feasibly develop. These capabilities reside in the particular mix of cultural, formal and technical knowledge of the labour force. This perspective views a product as a complementary set of knowledge and competences that need to be combined. Products that share similar sets of knowledge and competences are related, and they belong to the same "technological knowledge community". The skills sets of a knowledge community can easily be re-combined for the development of other related products. The nature of knowledge and competences available in a country's labour force, and the technological knowledge communities that have been developed, determine those goods and services that can potentially be produced. Diversification within existing knowledge communities describes an incremental or path-depending process of structural transformation (Nübler, 2014b).

Second, social capabilities determine the performance of economies in taking advantage of the opportunities to innovate, and in managing the processes of change, the search for new solutions, and

mobilising incentives to invest and entrepreneurship. These capabilities reside in the institutions of a society, and in particular in the rules and procedures which establish an institutional framework. They determine performance of an economy in product innovations, structural transformation and the creation of more and better jobs.

Finally, this theory argues that societies differ in their knowledge base and therefore also in their capabilities to innovate. Capabilities evolve in a collective learning process in schools, in social networks and in the production process. This implies that countries develop different knowledge and belief systems, a specific mix of knowledge and competences in the labour force, and country-specific rules and procedures provided by the institutional framework. Countries even with similar factor endowments and comparative advantages (determining cost structures), may differ substantially in the social capabilities to innovate, diversify and transform economic structures (Nübler, 2014b, 2017 forthcoming). These different capabilities across countries are seen as major determinants of the job-creating adjustment process. They shape the feasible pattern of product innovations and therefore the level and structure of new jobs and employment. Depending on the nature of capabilities embodied in societies, the future impact of automation and fragmentation on level and structure of jobs can be expected to differ across countries.

### **3.3 Evidence from digitisation: Impact on employment level and structure**

The most recent wave of technological change which has been introduced by the micro-processor at the beginning of the 1970 was driving digitalisation of production technologies. Since the 1980s, automation (robotisation) and fragmentation of production systems (new information and communication technologies and GVCs) were driven by digital technologies.

The period during the 1990s and the 2000s provides an interesting case for the analysis of the impact of robotisation and global fragmentation on employment. Digitalisation and globalisation had gained significant momentum at the end of the 1980s, and employment was not yet affected by the financial crisis. This section analyses data on robotisation and globalisation and the impact on jobs and employment in developed countries between 1993-95 and 2007-08.

#### ***Automation and manufacturing jobs***

Interesting findings are provided by a study by Graetz and Michaels (2015) which analyses changes in robotisation in 14 different industries for a total of 17 OECD countries between 1993 and 2007. The study finds that all countries gained significantly in labor productivity. They calculate that on average across the 17 countries, robot densification from 1993-2007 raised annual growth of GDP and labour productivity by 0.37 and 0.36 percentage points, respectively.

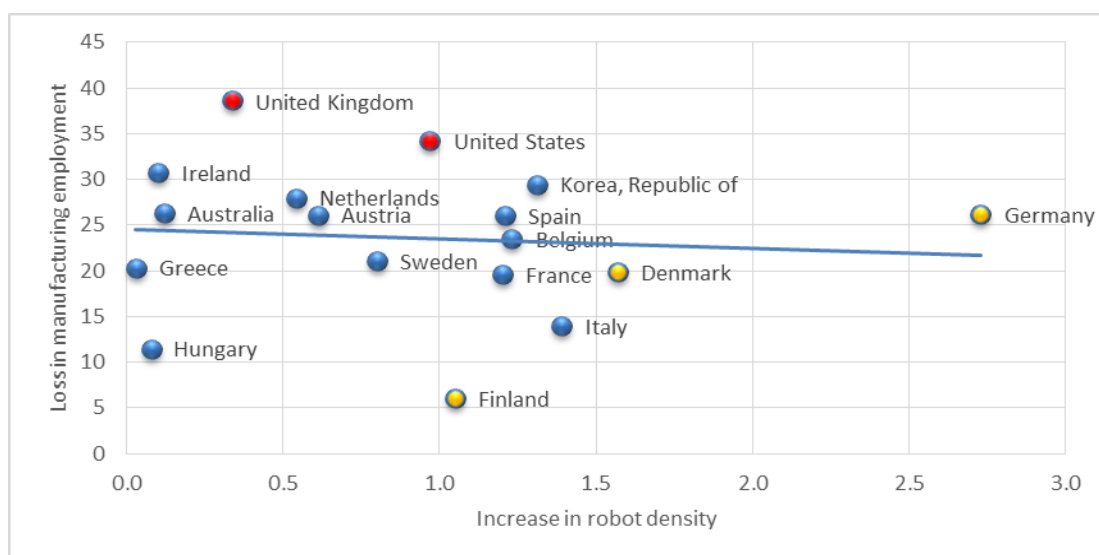
The study finds significant differences in the density of industrial robots (measured by the number of robots per million hours worked) across industries and countries. Interestingly, the differences in robot density were larger across industries than countries. Transport equipment and metal industries were by far the largest users of robots, with about 5.4 and 2.4 robots per million hours worked, while construction, education, mining, and utilities had negligible robot densities. From 1993 to 2007 the fastest increase in the number of robots per million hours worked took place in the transportation equipment, chemical and metal industries.

The most interesting question is how the increase in industrial robot density is reflected in the change in manufacturing net employment. Using the data on robot density provided by Graetz and Michaels (2016), and data on manufacturing employment as a share of total employment (ILO, 2016), we find no

statistical relationship between growth in robot density and loss in manufacturing employment, as shown in figure 2. Despite the fact that they had highest growth in robot density between 1993 and 2007, Germany, Denmark, Italy and the Republic of Korea lost significantly less jobs in manufacturing (as a share of total employment) than the US and UK, two countries with much lower growth in robot density in this period.

This implies that some countries were more successful in translating productivity gains from automation into output expansion, diversification and jobs than others, and in protecting manufacturing jobs in industries. For example, Germany's growth in robotisation resulted in increasing market shares in the car and electronics industry. Moreover, the country benefit from the rising global demand for digital production equipment and robots, and was able to expand the capital goods industry. Data shows that the export value in the machinery industry has more than doubled between 2000 and 2015 (from 79 billion to 155 billion Euro), and employment has increased by more than 10 percent (Statistisches Bundesamt, 2015). Today, the machinery industry is the largest industrial sector by employment.

Figure 2: Increase in robot intensity (number of robots per million hours worked) and decline in manufacturing employment as a share of total employment (in percentage), 1993-2007



Source: Data on robot intensity: International Federation of Robotics, provided by Graetz and Michaels (2016); data on employment: ILO KILM database (2016); own calculations

Finland demonstrated lowest levels of job losses despite a significant increase in robot density due to its impressive industrial growth from the late nineties to 2007. The country was able to generate new jobs in the emerging ICT and electronics sectors, driven by the global success of Nokia. The company sold nearly 41 million cellular phones in 1998, and became the world's top cellular phone maker in that year. Finland has faced unusual development with good job performance and extremely high productivity growth rates before the crisis. This was followed by a low or even negative growth rates and employment decline after 2007.

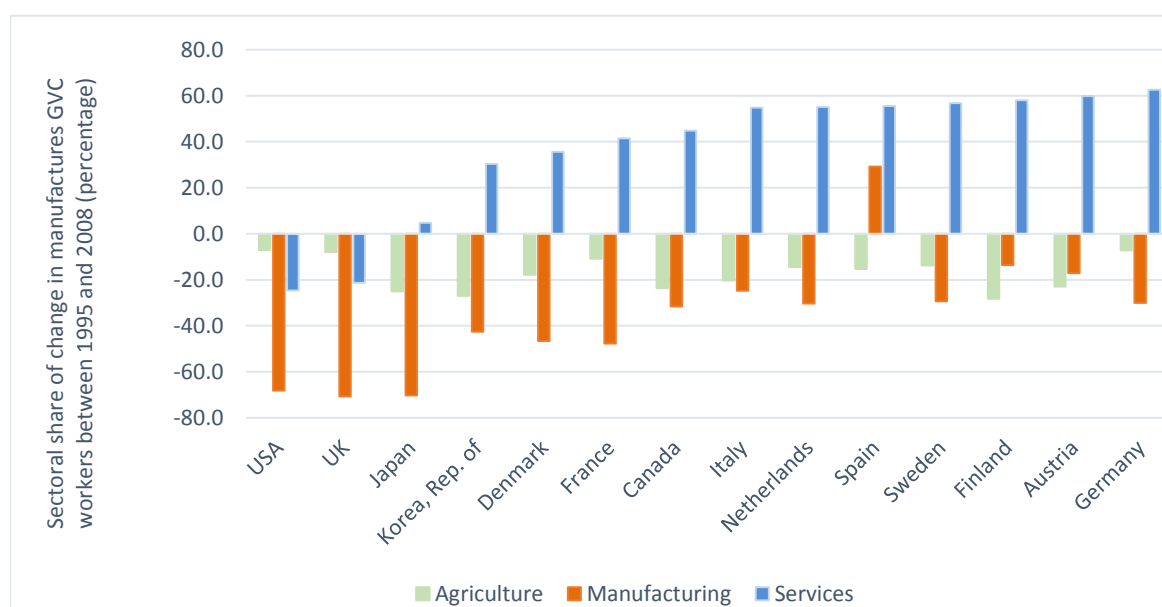
### *Fragmentation and GVC-related jobs*

The impact of production fragmentation in global value chains (GVCs) on employment has been analysed in a study by Timmer, Los and De Vries (2015). The study analyses data between 1995 and 2008, and by applying a new methodology to identify and measure GVC related jobs, it provides

interesting findings from 21 selected “major mature and emerging countries in the world” (selected European countries, United States, Japan, Canada, Australia and Korea).

This study reveals significant differences across countries. With the exception of Germany, where the employment share in GVCs remained stable, all countries saw a decline in GVC related workers as a share of all workers in the economy. What stands out is the massive decline and job losses in the United States, the United Kingdom, and Japan. This data suggests that participation of these countries in GVCs contributed significantly to the loss of jobs. As a result of GVC participation, only 11.1 and 12.6 percent of US and UK employment was involved in the global production of manufactures in 2008, respectively (see figure 3). This was around 26 percent of German which was by far the highest share across all advanced countries.

Figure 3: Change in manufactures related GVC workers employed in agriculture, manufacturing and services, 1995 – 2008



Source: World Input-Output Database (2012). Own calculations based on data provided by Timmer, Los, De Vries (2016).

Moreover, data shows significant differences in the pattern of change in GVC related employment across sectors. GVC related workers are directly and indirectly involved in the production of manufacturing goods. They therefore may be employed in agriculture, manufacturing and service sector, depending on the tasks and intermediaries they provide. Figure 3 shows two interesting findings in terms of changes in employment levels and structures. Firstly, the pattern of sectoral changes is almost identical for the United States and the United Kingdom, but different from the other countries. These two countries were the only ones which experienced a decrease of GVC related manufactures jobs in all three sectors. They lost workers in agriculture, manufacturing and service tasks which explains their large GVCs related net jobs loss. For example, the United States lost 331,000 jobs in agriculture, more than 3.1 million in manufacturing, and 1.1 million jobs in services. In the remaining countries, GVC related manufactures jobs were mainly lost in manufacturing tasks, with the exception of Spain.

Secondly, and this is striking, all the latter countries experienced significant increases in the share of service tasks, with the exception of Japan which could only achieve a small increase. In fact, half of the countries were able to fully compensate for the overall loss of GVC related jobs in manufacturing and



agriculture. For example, Germany lost around 66,000 jobs in manufacturing and 161,000 in agriculture, but gained almost 1.4 million jobs in service tasks related to GVC manufactures production.

Empirical evidence from the recent wave of technological change confirms that countries differ in innovation behaviour, in the pattern of industrial and structural change and the impact on jobs level and structure. It is interesting to find the difference in performance between the UK, US and Japan on the one hand, and Euro zone countries on the other hand. Between 1995 and 2008, manufacturing employment has been fallen to a significant higher extent in UK, US and Japan when compared to continental European countries. Moreover, while the former countries were unable to compensate for the loss of GVC related manufactures jobs by an increase in service-related tasks, many of the former countries could compensate jobs losses.

Furthermore, the difference between performance of the US on the one hand, and Germany on the other one is in particular interesting. They demonstrate different patterns of process innovations, as well as structural changes in the economy and in employment. Despite high levels of robotisation in industries and participation in manufactures GVCs, Germany was able to protect jobs by creating new jobs in manufacturing, e.g. in the capital goods sectors, and in GVC-related services. These different outcomes of market adjustment processes are, among others, a reflection of different social capabilities between these two countries.

### **3.4 The challenge: Understanding capabilities**

The challenge for researchers and policy makers is to better understand the nature of social capabilities that have created such significant differences across countries. Country-specific capabilities play a critical role in innovation behaviour. They shape the feasible patterns of structural transformation, the dynamics of the adjustment process, and the outcome of market processes in terms of job creation. This implies that the analysis of the impact of new technologies on the future of jobs needs to take into account country-specific social capabilities, and the options and limits they provide for markets to generate jobs.

#### ***Educational attainment structures***

Recent research at the ILO on capabilities and structural transformation has explored differences across countries in the knowledge base of its labour force, and how these differences in the structures of competences explain differences in production structures. One study was focusing on education systems and explored the differences in the educational attainment structure (EAS) (Nübler, 2017 forthcoming). While most research analysing the link between education and jobs focuses on educational attainment levels (measured in average years of schooling), the structural approach draws attention to the share of primary, lower secondary, upper secondary and post-secondary education graduates in the labour force. We distinguish between the “strong middle” and the “missing middle” EAS. The “strong middle” EAS takes the shape of a bell-curve when sorting educational attainment categories by primary, lower secondary, upper secondary and post-secondary levels. Strong middle EAS can be found, among others, in Germany, Austria, Switzerland, Denmark, Sweden, Finland and Republic of Korea. These countries also tend to have strong vocational training and apprenticeship systems.

In contrast, the missing middle EAS demonstrate a very low share of upper-secondary education graduates, but a high share of post-secondary education (at least 20 percent higher than the share of upper-secondary education). The United States, United Kingdom, Canada and Australia as well as France, Portugal, Italy and Spain have “missing middle” EAS. There is, however, an important

difference between the English speaking and the Latin language country groups. The gap between the upper-secondary and post-secondary education share is significantly wider in the former country group due to both, higher shares of post-secondary and lower shares of upper-secondary education shares (Nübler, 2017 forthcoming).

Most importantly, this research finds that the EAS represents an important carrier of capabilities to diversify and develop manufacturing. Cross-country studies show that missing middle EAS are associated with significantly lower shares of manufacturing (as a share of GDP and exports) when compared to the strong middle EAS. This finding holds for developed and developing countries. Hence, while the level of education is associated with the level of economic development, the capability to develop a particular economic structure is strongly influenced by the educational attainment structure.

Another research project aims at exploring the capabilities embodied in the technological knowledge of the labour force. This research has developed the concept of technological knowledge community (TKC) which determines all those products that require similar sets of skills, knowledge and competences in the production process. Products belonging to the same TKC are considered to be related, while “distant” products belong to different TKCs. Hence, we can think of the knowledge base of a society to be structured into a range of distinct technological knowledge communities. This approach provides a tool to analyse the core technological competences of emerging industries, and newly emerging hybrid occupations that recombine competences from existing TKC. Capabilities to innovate and develop new products are therefore shaped by the particular mix of vocational and technical competences, they increase with diversity and complexity of the knowledge sets embodied in the labour force, and technological learning is path-dependent (Nübler, 2017).

### *Institutional framework and redistribution*

The institutional framework is another important carrier of a society’s capabilities to drive diversification and product innovations. North (1990) argues that institutions provide rules (regulations, laws, norms) which guide and restrict human and organisational behaviour, develop trust and collaboration. Moreover, institutions mobilise support for change and reforms when they generate a sense of justice in society. Franck (1998) argues that this requires the procedures by which the rules were established to be considered as legitimate, and the distribution of the gains and burdens to be considered as fair. Acemoglu and Robinson (2012) highlight the link between inclusiveness of institutions, technological change and innovations. They demonstrate that inclusive institutions which benefit the large majority of a society foster technological change and innovation, while societies with mainly extractive or exclusive institutions (benefit only a small elite) tend to experience slow technological change.

This paper highlights the role of institutions in driving the adjustment process and in translating productivity gains into product innovation and jobs. While process technologies enhance productivity, the way these gains are distributed is critical for the dynamics of job creation. Institutions play a central role in the distribution of these gains. Firstly, while markets allocate productivity gains to the owners of capital and skills, institutions are needed to share these gains with low skilled workers and distribute them to consumers and creative entrepreneurs. A more equal distribution will increase purchasing power and demand, and transforms the structure of demand. Moreover, redistribution of productivity gains to creative entrepreneurs has the potential to support investment in start-ups, the development of new products and job creation.

Recent studies on the distribution of income demonstrate significant differences across countries. OECD data shows that for 2008, the income of the richest 10% is on average 9.5 times larger as for the



poorest 10 percent. These figures are around 7 times in France and Germany, but 10 times in the UK and in the US 16 times. This is also reflected in the differences in Gini coefficients which are relatively low for most European countries, but significantly higher in the UK and US. The New York Times reports on inequality in the United States (Blasi, Freeman, Kruse, 2015): *“The stagnation of earnings, despite rising productivity, and the shrinkage of the middle class, because of soaring inequality, are without precedent in our economic history. Capital’s share of national income has risen, while labor’s share has fallen. To restore prosperity for all, we need to spread the benefits of economic growth to entrepreneurial citizens through profit-sharing and the ownership of capital. This isn’t some radical notion; it has a long tradition in America.”*

Secondly, productivity gains can also be shared in the form of shorter working hours. Declining working hours create jobs by redistributing work as well as by increasing leisure time. More leisure time, combined with increased income and purchasing power, has always generated demand for new leisure related activities and products. While Keynes in his article of 1930 “Economic Possibilities for our Grandchildren”, famously predicted a future where the workweek would shrink greatly, liberating time for pursuit of “the arts of life as well as the activities of purpose”, working hours dropped only modestly in recent years, even during periods of rapid robotisation. Only few countries such as Korea, France and Germany saw a significant decline in their working hours during these periods (OECD, 2017). The low decline in working hours leaves room for further reduction and redistribution of productivity gains as a means to strengthen compensation effects.

Finally, the most recent debate on the future of jobs has raised the issue of “basic income” as a counter-policy measure. This would guarantee minimum living standards for all, irrespective of employment status, thus maintaining the consumption demand. Moreover, basic income is expected to strengthen the bargaining position of workers and wage shares, and by providing social security, it may strengthen incentives for workers to invest in skills and competences that may be in high demand in future labour markets. This idea goes back to Thomas More (in *Utopia*, 1516) and Thomas Paine (in *Agrarian Justice*, 1797) and has been repeatedly discussed during periods of great economic upheavals. The New York Times (2 March 2017) states that the Silicon Valley has recently become “obsessed with basic income ... as a palliative for the societal turbulence its inventions might unleash.”

In sum, the capability of a country to innovate is embodied in the intangible sphere of the economy. The mix of competences and the rules underpinning institutions are important carriers of capabilities, and they therefore will also determine the feasible dynamics of the adjustment process and of job creation. Researchers need to much better understand the country-specific capabilities and how they limit the ability of the economy to trigger a dynamic adjustment and job-creating process.

#### **4. Towards a golden age of job creation – A socio-political choice**

This section expands the analytical framework in order to explore the long-term dynamics of innovations, and the forces that have historically driven transformative economic change and jobs creation. While the previous section discussed job-creating adjustment processes that were driven by market forces and shaped by country-specific social capabilities, this section is focusing on adjustment processes at the social level. Evolutionary economics provides important insights into the co-evolution of technological, economic and social transformation processes. It shows that technological change is not linear, but comes in waves and cycles, and thereby drives the dynamics of job destruction and job creation. The unintended consequences created by past waves of technological change trigger societal learning processes, and establish new social and political choices. This dynamics goes beyond incremental product differentiation and diversification, but implies fundamental and transformational

changes which have been described by Schumpeter (1911) as a process of creative destruction. This dynamic element of the framework is critical for the current debate on the future of jobs.

#### **4.1 The framework of shifting techno-economic paradigms**

Evolutionary economics analyses the long-term dynamics of technological change and economic development. Dosi, Freeman and Perez have contributed to the development of a theory of techno-economic paradigm which distinguishes between revolutionary and evolutionary technological change, and argues that the discovery of fundamentally new technological knowledge creates a new technological paradigm. For example, new technological paradigms were introduced by steam power, internal combustion and electricity, and the most recent paradigm of robots and digital ICT emerged with the micro-processor in the 1970s. Once a new paradigm is established, the radically new scientific and technological principles which present the core of the emerging paradigm will shape the direction of R&D, the development of new techniques and the search for new exploitable opportunities and innovations. Industries which fail to shift into the new paradigm risk losing market shares rapidly. This was for example the case with Kodak which continued to produce cameras in the old paradigm when in fact the digital paradigm had been already established and has become the dominant technology.

Freeman and Perez (1988, pp. 47, 48) conclude that a new techno-economic paradigm results in “... a combination of interrelated products and processes, technical and organizational and managerial innovations, embodying a quantum jump in potential productivity for all or most of the economy and opening up an unusually wide range of investment and profit opportunities. Such a paradigm change implies a unique new combination of decisive technical and economic advantages”.

##### ***Three phases of a shifting techno-economic paradigm***

Most importantly, a shifting techno-economic paradigm comes in different phases and tends to span several decades. Perez identifies historical recurrences as a frame of reference to identify new techno-economic paradigms and the distinct phases of a shifting paradigm. At the beginning of a new techno-economic paradigm, a first phase is characterised by process innovations and is associated with huge productivity gains and job destruction. Workers and enterprises learn to apply the new technologies (e.g. electricity, digital ICT) in a process of “unlearning the old and learning the new”. For example, enterprises shifted from using mechanical to electrical typewriters, and in the current paradigm from electrical typewriters to computers. Communication and information technologies switched from analogue to digital technologies, and workers needed to learn the skills of the new paradigm.

The market-driven processes of technological change and adjustment described in sections 2 and 3 of this paper is essentially part of this first phase of a new paradigm. The quest for productivity drives process innovations and destroys jobs, while market forces drive adjustment processes that can create new employment. Firms innovate incrementally by improving the quality of existing products, and diversifying into new products (Freeman, 1992).

Perez, however, identified additional historical recurrences that characterize the first phase of a new paradigm. She argues that, while each historical period of technological change shows unique socio-economic development, the first phase of a new techno-economic paradigm has each time been accompanied not only by the explosive growth of productivity, but also by strong polarising trends in the income distribution, the development of technological hypes and of financial bubbles. In addition, an increasing mismatch has been observed between the economy and the regulatory systems. Regulatory frameworks developed to fit the requirements of the previous paradigm could no longer

cope with the new dynamics. “As the mismatch increases, tensions and decoupling processes rip apart the fabric of the economy, leading to problems of governance to questioning the legitimacy of the established institutional framework” (Perez, 2002). In fact, this period of technological change is perceived more as a threat than as the provider of opportunities.

The second phase of a techno-economic paradigm is called the golden age phase. Perez identifies several such phases in history, for example the Victorian Boom in Britain (after 1850), the Belle Époque in Europe at the turn to the 20th century, or the mass consumption phase following World War I. These phases were characterised by the development of new products, new markets, and the emergence of new industries replacing incumbent industries as drivers of growth. In other words, enterprises develop new ways of creating value. They drive product innovation, improve quality of existing products, and they create new industries and fundamentally transform the production structure. Perez and Freeman show that the second phase of the techno-economic paradigm is also characterised by new institutions, new regulatory frameworks and changes in consumption patterns which lead to interrelated product innovations. Perez argues that these phases not only created new jobs, but also better jobs. Golden age periods are characterised by a positive perception of technological and economic changes.

Finally, according to Perez, the golden age is phasing out into an era of maturity which is characterized by declining innovation dynamic and low productivity increase. For example, innovations in home electrical appliances during the 20th century began with the refrigerator and the washing machine and it petered out with the electric can-opener. This triggers the search for new technological principles that have the power to shift the economy into a new techno-economic paradigm.

#### *At the turning point: Social transformation for job creation*

Based on her framework of historical recurrences, Perez (2013) argues that advanced countries are currently at the turning point between the first and the second phase of the digitalisation, robots and ICT paradigm. Following an extensive period of process innovations and productivity growth, developed countries see “concentration of wealth increasing, income gaps widening, and jobless economic growth seemingly being the new norm in advanced countries.” Also the recent financial bubble in 2008 is interpreted to mark the end of the first phase of the current techno-economic paradigm. In fact, Perez considers the current position of advanced countries equivalent to the 1930s.

Perez argues that many economists and politicians have not yet realised that developed economies are now in a completely different context when compared to the 1960s and 1980s. They require new thinking, tools and policies in order to be able to shift into the golden age phase and to exploit its wide potentials for job creation. The path into such an economy requires structural changes and transformative policies which markets cannot achieve. It needs a new vision of society on the future, imaginative leaders and pioneer entrepreneurs that are aware of the current technological potential and the opportunities for job creation (Perez, 2016). The new vision transforms demand and consumption patterns, it mobilises new capabilities, creativity and institutional change. As work and consumption patterns change, also the way work and businesses are organized will change.

This framework suggests that developed countries today face the challenge to create new jobs by make the transition from the first to the second phase of the techno-economic paradigm. Such a transformation into the golden age phase cannot be achieved by markets, it is a socio-political choice. Governments, enterprises, workers and society as a whole need to develop a new consensus on the way forward, the new “way of life”, and the goals of development.

## 4.2 Transforming societies: A collective learning process

Evolutionary economics explains economic development essentially as a collective learning process. Transformative changes in production structures require societies to develop technological knowledge, new belief systems and new institutions. Theories of learning suggest that such collective learning processes may be triggered by different forces. On one hand, they are endogenously induced by the unintended consequences of technological change (Nübler, 2016). Unemployment, rising inequality, economic bubbles, financial crises and technological anxiety, deteriorating working conditions, as well as the effects of climate change have triggered learning processes, in particular when societies were no longer willing to tolerate the impact of these changes. Learning is expressed in new institutions and new social and political demand for fundamentally new types of goods and services.

History shows that unintended consequences raised concerns of some groups in societies which then launched broad debates and new social movements. They motivated scientists to search for new technological knowledge, and policy makers to develop new institutions and regulatory frameworks. This was the case, for example, with the newly developing industries in the 19th century which were not covered by the regulatory framework and institutions of the medieval guilds. As a result, the new factories as well as apprenticeship training developed low working conditions. They deteriorated to an extent that was no longer tolerated by most groups of society. Impoverishment of the masses, and the risks of political unrests triggered a debate among intellectuals, economists, religious groups, workers employers and governments which resulted in a collective learning process and new institutions. Labour parties, trade unions and social reform movements emerged throughout the industrialised world. These new institutions regulated the new industrial world of work, e.g. in Germany the social security laws (1880s), a regulated apprenticeship system (1901) and a regulatory framework for collective bargaining of workers and employers was established.

On the other hand, history shows that emerging technologies and the new opportunities they open up have triggered and supported the evolution of new ideas, philosophies, ideologies, expectations and attitudes. For example, the new ideas of the “Enlightenment” evolved with the new technologies leading to the Industrial Revolution. They were developed in a broad debate by prominent thinkers such as John Locke, Voltaire, Jean-Jacques Rousseau, David Hume, Immanuel Kant, Denis Diderot, and Benjamin Franklin. They all saw themselves as “educators of societies”. The new knowledge system gave human reason supremacy over religious beliefs, and promoted the idea of individual freedom. The wide diffusion of these new ideas fundamentally changed how people thought about business, exchange, innovation and profit, human liberty and dignity, and the role of education and training. It generated an “Engineering Culture” and the “Bourgeois Revolution” where the “elite of birth” was replaced by the “elite of wealth”. This new thinking contributed to technological change and industrialisation, and the wide diffusion of new scientific and technological knowledge. The “New Consensus” among economic historians is that the rapid development of new technologies in Western countries and modern capitalism was triggered and sustained by new culture, ideologies, and philosophies (McCloskey, 2010; Mokyr, 2002).

Another example is the belief system that supported the development of the so-called consumer society and the golden age phase of the 1950-60s. Fromm (1976) explains how modern society has become materialistic and prefers “having” to “being”. He mentions the great promise of unlimited happiness, freedom, material abundance, and domination of nature, and the social status which was increasingly linked to “having”. The literature on the varieties of capitalism explains the endogenous change of regimes of economic growth (see for example Hall, 2015).

### 4.3 The future: A golden age of job creation?

The framework elaborated in this paper suggests that developed countries are currently at the turning point within the digital techno-economic paradigm. The fundamental challenge is to bring about transformative changes in societies and economies to make the transition. This raises the important question whether countries will be able to mobilise a societal learning process that will lead to new social and political choices, new social capabilities and the golden age of job creation.

Many of the current debates we observe at the international level and at country levels can be interpreted as part of this learning process. These are in particular the debates that address rising tensions between established institutions and the economy, unintended consequences of technological changes, the shift in the development debate from productivity growth to structural transformation, and the new debate on the role of the state in R&D, innovation, investment, structural transformation and jobs generation. Many of these debates have gained momentum during the past few years. The challenge is to use these debates and social dialogues to work towards a common understanding and consensus on the future.

The international debates, and the social and political movements we observe in many countries reflect a concern about the adverse effects of technologies in societies and the natural environment. The debate on climate change has mobilised wide support and resulted in an international agreement achieved in Paris (COP21). High and rising inequality is on the agenda of many economists. The recent publications by Piketty (2014), Milanovic (2016), and of international organisations, including the IMF, has attracted substantial attention. The most recent papal encyclical (June 2015) challenges the “technocratic paradigm” which “accepts every advance in technology with a view to profit, without concern for its potentially negative impact on human beings”. Another emerging debate is on basic income, and most interestingly, many countries are now launching basic income pilot projects.

Moreover, economists have launched a major debate on the importance of structural transformation and the role of the State in targeting industries and technologies. This debate challenges the Washington Consensus which focuses on growth, efficiency and markets. An emerging debate in academics and in policy circles is focusing on the role of governments in financing mission-oriented R&D and innovation activities, and in promoting public investment in order to crowd in private investment (Foray, 2009; Mazzucato, 2013). Also industrial policy is back to the agenda in many countries, and has regained significant support in academic and policy circles. There seems to be a growing awareness that economies are currently in a situation where job creation requires transformative changes and a proactive government to support these processes. In a recent article, Perez (2016) states: “... just as in the 1930s, there is an enormous technological potential lying dormant because finance sees all innovation as risky and stays in its own world ... rather than funding the real (riskier) production economy. ....The potential is there for jobs, growth and wellbeing. Yet these will not come without innovation and investment. And finance for them will not be forthcoming before the context is shaped to make them profitable and less risky. ...The solution is available, but the leaders are asleep.”

Finally, the thriving debate on skills mismatch may be interpreted in the context of shifting techno-economic paradigms. A growing body of research at the ILO, CEDEFOP and OECD aims at explaining the phenomenon that despite high investment in education and training, many enterprises cannot find the right type of skills in the labour market. Anticipation of future skills needs has therefore become a main policy advice to cope with widening skills mismatch. This debate, however, may also reflect a more fundamental issue. Perez has highlighted the mismatch between the established institutional framework and the new requirements of an economy. As countries approach the turning point, this tension will be growing. Hence, while the debate on education and training during the 1980s and 90s focused on skills-biased technological change and skills shortages because digital process innovations



triggered rapid demand for the digital skills which resulted in skills shortages, the debate on skills mismatch since the mid 2000s relates to a different phase in the techno-economic paradigm. A recent survey of more than 1800 business leaders, technologists and academics in the USA raised concern that “our educational system will not prepare us for the work of the future, and our political and economic institutions are poorly equipped to handle these hard choices” (Smith, 2014).

Countries are now challenged with generating product innovations and structural change, which challenges education and training policies to reform institutional frameworks and generate competences, mind sets and attitudes that are needed to make the transition into the new sectors. The main issue in education and training today is no longer about “what skills should be delivered” but “how to train the labour force” and what institutions are needed to generate the knowledge base and social capabilities that allow the economy to create new jobs in new sectors.

## 5. Conclusion

This paper develops a framework to analyse the impact of new technologies on the future of jobs. It explains the link between technological change, innovation and jobs, and the dynamics of job destruction and job creation. The framework shows that technological change and innovation is a complex, non-linear and non-deterministic process which comes in waves and different phases, and thereby destroys and creates jobs.

The framework discusses automation and fragmentation of production processes as two forms of process innovation that have triggered waves of job destruction in the past. The creation of jobs is explained endogenously as the result of adjustment process. Process innovations generate unintended consequences which trigger job-creating adjustment processes. In the short term, market forces create new jobs by expanding markets or diversifying into new goods and services. The outcome of market processes, however differ substantially across countries. Country-specific social capabilities determine and limit the range of products a country can feasibly develop, and the jobs it can create.

Most importantly, this framework shows that a golden age of job creation – the generation of new jobs at a massive scale - requires transformative changes, the emergence of new growth sectors and a process of creative destruction. Such fundamental changes cannot be achieved by markets. They require new social and political choices and new social capabilities, which can only be developed in a process of societal learning and social transformation.

A major conclusion of this paper is that the future of jobs is not deterministic. Governments and social partners are challenged with shaping the dynamics of the technological, social and economic transformation process that generates new jobs. Empirical analysis of recurrences suggests that developed countries are currently positioned at the turning point where they are challenged to move from a phase of net job destruction to the next phase of net job creation.

This paper concludes that we can be confident that history will repeat itself also this time and create new jobs **if** societies will be able to mobilise a learning process that generates a new vision on the way forward and on development goals, and a common understanding of how to move towards this future. Institutions that support social dialogue and societal learning will therefore play a central role in generating transformative product innovations and new jobs. Finally, research on new technologies and the future of jobs needs to broaden its focus. While the current focus is on job destruction, researchers and policy makers needs to gain a better understanding of the job-creating process, and how public policies can effectively shape them. This implies that research needs to shift attention from the “technical” to the social and political dimension of technological change, innovation and job creation.

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