Sharing the Benefits of Innovation-Digitization

A Summary of Market Processes and Policy Suggestions

Roumeen Islam

WORLD BANK GROUP
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Abstract

Governments play a very important role in supporting innovation, managing the disruptive effects of innovation, and ensuring that the benefits of innovation are broadly shared in the long run. This paper reviews the literature on market mechanisms that translate innovation into jobs and policies that are needed to improve outcomes. Although many countries now recognize the importance of modifying fiscal redistribution and insurance mechanisms to deal with the challenges of the digitization age, no country has yet done so feasibly. Developing country governments, having lower institutional capacity and usually fewer resources, will likely find it even more difficult to manage these changes. Global production patterns are likely to continue shifting. These shifts will depend on a combination of factors: the direction of technological change, trade agreements, global demand patterns, policies, and endowment shifts. Developing countries may not follow the same structural route of the past, through manufacturing, to higher income, but with appropriate investments, they can develop high-productivity service sectors. The policies that are needed to harness the benefits of digitization span a wide range of sectors: finance, competition policy, public support to innovation, fiscal and regulatory incentives for innovation, macroeconomic frameworks supporting demand growth, public support to education and reskilling, infrastructure provision for the digitization age, and sustainable fiscal insurance and redistribution systems. Finally, a lot more research needs to be done to understand how the gig economy affects the welfare of workers of different types, its macro effects, and how digitization interacts with an aging or shrinking labor force in the growth process.

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What do Charlie Chaplin and Mahatma Gandhi share? *Modern Times* is a 1936 silent comedy film written and directed by Charlie Chaplin in which his iconic Little Tramp character struggles to survive in the modern, industrialized world. The film is a comment on the desperate employment and financial conditions many people faced during the Great Depression, conditions created, in Chaplin’s view, by the efficiencies of modern industrialization.

*Modern Times* portrays Chaplin in his Tramp persona as a factory worker employed on an assembly line. There, he is subjected to such indignities as being force-fed by a malfunctioning "feeding machine" and an accelerating assembly line where he screws nuts at an ever-increasing rate onto pieces of machinery. He finally suffers a nervous breakdown and runs amok, throwing the factory into chaos. He is sent to a hospital. Following his recovery, the now unemployed factory worker is mistakenly arrested as an instigator in a Communist demonstration. In jail, he accidentally ingests smuggled cocaine, mistaking it for salt.

During a European tour promoting *City Lights*, Chaplin got the inspiration for *Modern Times* from both the lamentable conditions of the continent through the Great Depression, along with a conversation with Mahatma Gandhi in which they discussed modern technology. Chaplin did not understand why Gandhi generally opposed it, though he granted that "machinery with only consideration of profit" had put people out of work and ruined lives.²

The fear of job loss with automation has been around for a long time. Yet society prospered. Public policy can soften the negative consequences of economic disruption while supporting the path to greater prosperity.

² [https://en.wikipedia.org/wiki/Modern_Times_(film)] (October 2017).
Sharing the Benefits of Innovation

Introduction

Societies around the world are concerned with the shock to jobs and income resulting from automation, or more broadly, digitization. Policy measures to manage the employment disruption are under discussion. This note presents a broad-brush picture of the main policy options being discussed to manage the disruptive effects of technological innovation on employment. It does so by exploring some of the representative literature that covers the issues and policies. While no country has a ready, self-financing package of solutions to simultaneously protect those who lose, while supporting technological advancement, there are many policy possibilities. These possibilities and their implications are presented after a brief summary of the research that examines the impact of technology on employment.3

Labor-saving innovation in human history: Technology at “work”

The ultimate value of innovation lies in its ability to improve peoples’ standard of living by raising their income, allowing them more leisure and more services or goods to enjoy during their leisure, or improving other aspects of life. Through history, labor-saving innovation has raised human welfare: higher output and growth accompanying rising labor productivity has ensured new jobs to replace old ones. The market distribution of gains or losses from innovation has varied across time as new tasks were discovered. People first built mud houses with their own hands, then wooden and brick ones, then they were replaced by machines4 that built them on a larger scale and faster, while some concentrated on building and guiding the machines, others designing and making better bricks and

3 The paper does not provide an in-depth discussion of the large and increasing literature on digitization, skills and education.
4 Though not in all countries- due to the large income and technology gap.
construction materials, and still others designing better buildings and doing other complementary (to machines) and value-adding activities. Some did none of these things. Most people got better houses, different work and new goods and services not related to houses as countries moved up the technology ladder. Society’s wealth increased, even while some were left behind temporarily. Historically, workers have enjoyed a decline in the total number of hours worked to produce this varied and rising output. The last two centuries have seen average yearly working time halving from about 3,200 to about 1,600 hours per year (Maddison (1991) and Sangheon, McCann and Messenger (2007)); see Figures 1 and 2 below. Of course, averages and totals do not disclose the distribution of benefits or the short-run disruptions in economic activity resulting in unemployment, nor does they give any idea of how the transitions may be managed to minimize loss to society.

**Figures 1 and 2**

**Hours worked per worker versus total hours worked and per capita hours worked**

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**OECD Total**

Hours Worked per Worker vs. Total Hours Worked

**OECD**

Hours Worked Per Worker vs. Per Capita

**EU Countries Total**

Hours Worker Per Worker vs. Per Capita
This paper does not address the myriad (and vast) ways in which the digital revolution can increase productivity and growth and enhance access to goods and services for the disadvantaged in society. The potential gains are large. They are potentially even larger for developing countries that have yet to adopt the technology, digital and otherwise, of those at the frontier; and the digital technology frontier is yet to be discovered. Whether it be in agriculture, health, manufacturing, mining, or finance, human lives are being transformed as individuals, as members of society, and as participants in factor and product markets. This paper only deals with one aspect of the ongoing transformation of markets: managing the effects on employment and loss in income due to digitization-led unemployment.

Innovation by its nature is always “disruptive” as it changes economic profitability, market structure, and substantial innovations can dramatically affect potential output.\(^5\) The Luddite revolution period of the early 1800s resembles many other episodes where unemployment engendered by innovation hurt groups of people by changing market profitability and structure, but automation (mechanization) also changed growth and potential output. By affecting relative prices, innovations change society’s norms and expectations. With access to clean, affordable, piped water, it was more acceptable for girls (traditionally water-carriers) to attend school. The “unemployment” of girls in water collection was a good development. Historically, the former type of unemployment engendered by innovation has varied in duration, scope, magnitude and distributional impacts.\(^6\)

\(^5\) The more substantial the innovation, the higher the gap between actual and potential output.

\(^6\) Analysis looking at historical developments has differentiated between the employment effects of labor-displacing process innovations versus product innovations, between innovations that could be used across a range of industries (general-purpose innovation like the steam engine), versus those that had value in only one production sector (e.g. medicines in the health industry) in terms of their job impact.
Profit-sharing between the innovators, those who commercialize the innovation (who may or may not be the initial innovators), and others has been at the forefront of modern history and policy. For example, countries have varied in terms of who owned the initial innovations (e.g. Thomas Edison and other researchers for the light bulb), or who was able to capture associated profits by commercializing upon the invention (e.g., the light bulb producers, including Edison and Swan, consumers, other producers), who built upon it (e.g. Nikola Tesla, who developed AC transmission and generation technology, consumers, factory owners, retailers etc.), how fast and widely it all spread (depended on demand, infrastructure, etc.), and what type of market structure prevailed afterwards (e.g. free entry, low entry costs, in the light-bulb producing and retail industries, or in the general electricity sector; Edison filed for a patent). Social unrest is more likely when technological change fails to improve the lot of visible chunks of the population, takes away their jobs, or raises inequality for long periods.

While cognizant of the role of employment-displacing innovation in raising welfare, concerns with digitization today are being fueled by: (a) a pace of change in markets that is perceived to be much faster than it was for previous episodes of innovation (Figures 3-5 show the diffusion rate of some recent inventions); (b) fast movement of digital innovations across borders, faster global impact, competition and feedback channels. For example, a Citi GPS study (2017) cites that it took on average 119 years for the spindle to diffuse outside Europe, while the internet spread across the globe in only 7 years (and now cross-border hacking is common); and (c) the spread of AI is affecting a (hitherto unexpectedly) wide range of human tasks across the population. With digital technology spreading so fast, there are bound to be large intertemporal and spatial disruptions in employment. For example, manufacturing using sophisticated technology and 3D printing may bring more U.S. companies home

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7 Digital technology has several facets ranging from information provision on the internet to replacing a variety of services by AI (Citi, 2016, Autor 2017). The term digitization will be used to encompass all these effects.
from foreign countries offering cheap labor. Automation and AI are already making Indian IT workers redundant in some services. The social consequences of very fast-paced technological developments, especially large and complex ones, are hard for policy makers to manage.

Figures 3-5: Accelerating technical change

3: Trend in patent applications for the top five offices, 1980-2015

![Graph showing trend in patent applications for the top five offices, 1980-2015.](image)

Note: The top five offices were selected based on their 2015 total.

Source: WIPO Statistics Database, February 2017.

4: Time to reach 50 million users

![Bar chart showing time to reach 50 million users for various technologies.](image)
Source: Citi Digital Strategy Team (Benedikt Frey and Osborne 2015)

5: Accelerating consumption spreads

![Graph showing percent of U.S. households for various inventions](image)

Source: Michael Felton, The New York Times

**Theory: Economic processes by which innovation affects labor demand and employment**

*What will happen to employment?* A burgeoning literature analyzing the effect of technological innovation on labor markets has found demand for labor of different skill types shifting over time. More recently, the literature refers to different types of tasks performed by labor, ranging from rote tasks and tasks requiring physical strength to those requiring creativity, social skills, higher education and other high-level cognitive aptitudes. This paper does not repeat this literature, though the annex provides some references to it. Rather the focus is on market mechanisms that have raised labor demand and employment over time and policies that support this process, recognizing that on the one hand, demand for labor is derived from the production of goods and services and on the other, that innovation by labor (people) and changing tastes\(^8\) drive the production of (new) goods and services.

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\(^8\) For example, consumers may boycott goods produced by child-labor or those with a large carbon footprint.
In fact, the importance of consumer preferences in shaping output demand, (and thus factor demand) is demonstrated by examples such as the move towards organic foods, or a preference for synthetic fibers away from silk. The WSJ reports recently (Oct 23rd, 2017): ⁹

_Reckitt Benckiser Group PLC, one of the world’s biggest suppliers of retail brands, is splitting the business into two divisions.... reasoning that tighter focus is more important than scale for products like Lysol, Woolite, and Mead Johnson baby food. Splitting the business into home-and-hygiene products and consumer-health goods makes Reckitt the latest supplier to act amid stalling sales as consumer tastes in many key markets change fast. Shoppers are gravitating toward smaller, local products and away from mega-brands._

**Process (in lieu of labor) versus product innovations.** An important distinction is usually made between process innovations, where machines are replaced by humans in existing production processes versus product innovations (new goods or services are produced requiring human intervention). Digital technology affects both types. Not all process innovations displace labor, however, using drones to take photos of agricultural crops may not displace any human labor being a new task, while using robots to serve at tables in restaurants does. Product innovation has tended to be employment-friendly. Most process innovations have been in the form of embodied technical change (ETC) – technical change embodied in new capital goods. Using European Community Innovation Surveys and other data, recent micro-econometric studies confirm that firms that spend more on R&D generally do more product innovation while ETC is linked to process innovation (Conte and Vivarelli, 2005 and Parisi et al, 2006). The literature discusses a number of “compensation” mechanisms (Vivarelli, 2014, Dobbs et al, Oxford Economic Papers,1987) whereby the initial and direct negative impact of labor-saving technology on

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⁹ Anecdotally, preferences among high income groups continue to shift in favor of organic food produced by local farmers, in smaller scale, away from the mass-produced, pesticide-treated agricultural products of the post-industrial revolution age. Maybe one day, we will eschew all goods produced by robots in favor of those solely produced by humans!
labor demand may be counteracted by a positive push to labor demand and employment via market processes, helped by policy.

**Economic mechanisms by which markets compensate employment losses due to labor-saving innovation.** Vivarelli (2014) and Spiezia and Vivarelli (2000, in Pianta and Vivarelli ed., 2000) among others, highlight “compensation” mechanisms that could counter the immediate labor-saving impact of innovations. Studies examining each of these compensation methods find that some are more relevant than others in practice:

(a) *Workers displaced by process innovations find jobs in the industry producing these same machines.*

Rarely has mechanism (a) been a source of substantial compensation for labor (demand and employment). Employment in the machine-making industry will not make up for losses in employment in the retail industry, for example.

(b) *Productivity gains are passed on to consumers in the form of lower prices. Lower prices raise demand, output and employment.* Mechanism (b) relies on demand elasticities and factor substitution elasticities. For example, a large factor substitution elasticity implies a larger relative decline in labor demand while a large price elasticity for demand means higher demand for the now cheaper goods (assuming prices fall to reflect lower costs of production). While there may be some compensation via this method, there may also be factors working against compensation, such as, demand constraints, or consumers holding more financial assets and hoarding extra cash,\(^{10}\) or inflexible prices.

(c) *Part of the decrease in costs may be kept by firms as profits which would be reinvested. Investment raises production and jobs.* Mechanism (c) may not arise due to market structure (monopolies and oligopolies are less likely to increase investment or output or lower prices in response to an increase in

\(^{10}\) The link between investment in financial and “real” capital is not necessarily strong as recent evidence has borne out. See also (Davidson, 2002).
demand) or other factors such as low confidence. Macroeconomic factors, such as expectations of lower
demand, overly restrictive fiscal or monetary policies or higher investor risk will constrain the output response.

(d) Wages adjust so that labor demanded rises. Adjustments through wages are also problematic. A
lower wage to clear the market for unemployed workers is a limited remedy as these workers may not
be re-hirable. Second, aggregate demand falls when there is unemployment and reduces
“compensation”.\(^{11}\) In addition, even if wage declines reduce unemployment, they may exacerbate
inequality.

(e) The increase in wages for those remaining employed means higher incomes, higher demand, higher
output and jobs. Increased demand by those remaining employed has not proved to be sufficient
compensation alone for the many that become unemployed.

(f) New products will lead to output and jobs increasing. Mechanism (f) is the most robust over the long-
term and has been the source of much employment growth. The main issue with this mechanism is that
it is hard to predict what the new products will be and when markets will be developed for them. The
potential to create new products differs across countries, depending on endowments and initial
conditions.\(^{12}\)

A complicating factor is that the dynamic employment impacts of innovation are unpredictable,
even if the mechanisms are known: (a) firms differ in how fast they adopt innovations over time; (b) the
full potential of an innovation may not be realized immediately (whether it be electricity, or the
internet); (c) an initial innovation in one field may spur others (medical robots, military drones,

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\(^{11}\) Vivarelli (1995) discounted the compensation effect through wage lowering as it was not reasonable since
demand was expected to fall with a decline in wages. Moreover, just lowering wages does not induce firms to
divest of their new capital.

\(^{12}\) Vivarelli (2014) compares the labor-intensive production effect of cars and durables in the 1950s and 1960s with
the relatively less labor-intensive effect of home computers in the 1980s and 1990s.
driverless cars); and (d) policies and institutions supporting innovations evolve over time. Moreover, extrapolating the effects from one country, where most of the innovation is conceived and tested, to one where it may be adopted, is not straightforward. (e) Countries differ in terms of their market specificities, policies or endowments.

Empirical findings: Summary\textsuperscript{13}

The main findings, with the caveat that the future and past may be different, are that (1) R&D tends to be associated with product innovations and employment growth; (2) higher consumption and investment demand are both important in the process that raises employment; population growth and changes in the composition of income are important determinants of the increase in demand; (c) the location of demand spillovers influences the location of employment growth; (d) financing for all types of firm sizes, and for innovators as well as those adopting innovations is key; (e) the pace of digitization varies substantially between countries; (f) the welfare impacts of new technology differ across time and space; and (g) the changing demand for skills is an old phenomenon.

Various types of studies are needed. Firm-level analyses capture the reasons and modalities by which firms undertake innovation, but they cannot capture spillover effects among firms and sectors. For example, finding that innovation increases employment at the firm level and concluding that innovation and employment are overall positively related could be wrong. Not all firms innovate and those that do not can lose market share or exit and the effect of these overall dynamics would be negative for employment.\textsuperscript{14} Firm-level analyses also miss intersectoral linkages and they do not provide insights into aggregate labor dynamics. Sectoral studies can capture cross-firm spillovers, and more of

\textsuperscript{13} This paper does not provide a comprehensive list of all the papers, but enough of a collection to illustrate the main conclusions.

\textsuperscript{14} Note that at the level of the single firm, innovative firms tend to be characterized by better employment performance as they gain market share and even with labor saving technology they can end up hiring more labor, if they expand output sufficiently.
the aggregate dynamics. Macro-econometric analysis accounts for all the direct and indirect effects of innovation and therefore gives a fuller picture of aggregate dynamics and employment. However, in macro-econometric analysis it is difficult to find an appropriate proxy for technological change and these analyses are affected to a larger extent by cyclical conditions, overall labor market dynamics, and other factors that are hard to control for, such as, trends in variables over time (such as working hours) and various institutional elements.

**Product innovations tend to be more employment creating than process innovations.** Harrison et al (IJIO, 2014) do a firm-level analysis of process and product innovations for France, Germany, Spain and the United Kingdom during 1998-2000 and find that while process innovations tend to reduce employment requirements per level of output, the growth of demand for the old products (due to a reduction in their price) and the growth of demand for new products, together, more than compensated for the reduction in employment. In a study of 16 industries in Germany, Zimmerman (1991), using a long panel data set of German manufacturing firms, finds that overall unemployment was higher as a result of technical advance in the 1980s. Benavente and Lauterback (2008) using firm-level data for manufacturing firms in Chile during 1998-2001 find that although improvements in productivity diminish employment, the increase in total sales works as a compensation effect, rendering the total effect on employment positive. They conclude that product innovations increase output and employment, particularly if the new goods are not substitutes for existing goods. Alvarez et al (2011), examining the relationship between employment growth and innovation in the manufacturing industry in Chile during 1995-2007, find that process innovation has statistically ambiguous effects on employment growth, but product innovation is usually positively related to employment growth, regardless of firm size, and in both low and high-tech industries. Antonucci and Pianta (2002) find an overall negative impact of technological change on employment in manufacturing industries across four European countries. Evangelista and Savona (2002) find a positive employment effect in the most
innovative and knowledge-intensive service sectors and a negative one in the case of financial-related sectors and most traditional services like trade and transport. Greenan and Guellec (2000) using French manufacturing sector data over 1986-90 find a positive relationship between innovation and employment at the firm level, but at the sectoral level only product innovation was associated with job creation. Simonetti et al, in Vivarelli and Pianta (2000), do a macroeconometric study comparing Italy, Japan, the United States and France, specifically looking at the impact of process innovation during 1965-93. They conclude that countries lagging behind technologically and therefore depending more on innovation developed in other countries (Italy and Japan in their sample) see a strong negative relationship between employment (and process) innovation, in the period that productivity rises. During the period of analysis, France and the United States did more basic research (R&D). Investment was also more strongly related to innovation in Italy and Japan; innovation was embodied in gross investment. However, the relationship of innovation and investment is negative in the United States and France during that period.16

R&D fosters product innovation within firms and supports employment growth across sectors.

In sectoral analysis, Bogliacino and Vivarelli (2012) examine one of the compensation mechanisms by which employment may grow after labor-saving innovation is adopted. They study 25 manufacturing and service sectors for 16 European countries over the period 1996-2005 and find that R&D expenditures fostering product innovation have a job-creating effect. Mario Pianta (in Pianta and Vivarelli ,ed.), find that at the firm level, R&D expenditures generally reflect product, rather than process innovations and are associated with employment growth.17

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15 They use patent data from the U.S. Patents and Trademarks Office to distinguish between process and product innovations.
16 Innovation was not embodied in new capital goods or was in sectors that were not physical capital -intensive.
17 Piva and Vivarelli (2004), studying a sample of 318 manufacturing firms in Italy over 1992-97, find innovation raises employment within the firm in Italy.
Market competition affects investment and consumption growth and therefore labor demand.

Tancioni and Simonetti (2002) develop a macro-econometric model to examine the complex relationship between technology and employment. Estimating relationships for Italy and the United Kingdom, they find some strong differences in the “compensation” mechanisms at work in the two countries in response to innovation/supply shocks, due to structural dissimilarities between the countries. For example, the consumption response depends significantly on wages, employment and profits in Italy, while in the United Kingdom, it is driven mostly by changes in prices. They conclude that a less competitive market structure in Italy means that producers are more able to appropriate productivity gains, rather than passing them on to consumers through lower prices, thereby muting compensation effects through this channel. To the extent that labor unions are stronger in Italy, there may be a smaller reduction in employment or a larger increase in wages (and therefore in consumption). 18 19 In Alvarez et al (2011) excess bureaucracy and the state of bankruptcy law are additional obstacles to competition preventing the creation of new business (and investment). They argue that legal restrictions on immigration similarly limit competition. These factors will tend to hinder employment growth. However, there are complicating effects. Firm profits are more important for investment in Italy than in the United Kingdom. They interpret this to mean that firms are more dependent on internal finance in Italy, where the financial sector is less developed than it is in the United Kingdom. Investment requires financing and compensation through the investment channel will work better when firms have internal finance/profits (and therefore, more market power), when the financial system is less developed. In comparing the

18 These compensation channels are generally not strong.
19 However, the effects operating through wages and employment in the innovating firm are less likely to have large effects on total demand. Similarly, the innovation could be small enough that price falls only affect a small proportion of consumers.
United Kingdom and Italy, they contend that the differential development of the financial sector is important in explaining the differences in responses.

Other papers also discuss how price elasticities and the degree of market competition or concentration affect compensation mechanisms in practice. Dobbs et al (1987) contend that where output demand is more price elastic, producers are more likely to reduce prices and raise output, so the demand for labor is more likely to increase and more likely to swamp the labor substitution impact of new technology. Industries facing international competition are more likely to face elastic demand curves than those that do not.\textsuperscript{20} Barkai (2017) does an analysis of the U.S. nonfinancial corporate sector in the period 1984-2014 to explain the declining share of labor in output. He contends that when technology reduces the labor share, the capital share in output must increase if markups are constant. He finds that markups have increased dramatically in the United States. Sustained markups are associated with lower competition in markets.\textsuperscript{21} Thus, the cost of capital has declined, yet firms have not increased their investment rates commensurately. As a result, the capital share of output\textsuperscript{22} has declined substantially too. He finds that industries that experienced larger increases in concentration also saw larger declines in labor shares. His paper underscores the importance of higher investment and output in playing an important “compensation” effect in determining the overall impact of innovation on employment (and wages).

Dottling et al (2017) analyze private investment in Europe and the United States over the past 20 years. They find that investment has been weak in both places, but for different reasons. In Europe, investment movements have been more cyclical with financial constraints playing a role during the

\textsuperscript{20} Note that in industries facing foreign competition, if labor resists technical change, then they may be more likely to suffer in terms of reduced labor demand.

\textsuperscript{21} He concludes that the model of competitive markets was more relevant in 1984 when profits were close to zero, than it was in later years.

\textsuperscript{22} This is measured by the required rate of return to capital times the stock of capital used divided by value added.
financial crisis, especially in Spain and Italy. However, it is generally in line with Tobin’s Q for most countries. In the United States, investment is lower than predicted by fundamentals, as there is low investment despite high Tobin’s Q, starting around 2000. The gap is driven by industries where competition has decreased over time, as evidenced by increased concentration and decreased anti-trust enforcement in these industries. De Loecker and Eeckhout find that U.S. firm market power—as measured by the markup of prices over costs—was roughly stable between 1950 and 1980, but has increased steadily since then, with markups increasing from 18% in 1980 to 67% in 2014. They find that most of this rise is attributable to an increase in the markups of the firms that already had the highest markups. They argue that this increase in market power may help explain several macroeconomic trends, including the decline in the share of income attributed to labor, falling labor force participation, and the slowdown in output growth.

Furman (2016) has similarly noted the decline in market competition and its relationship with investment in the United States. In sum, if market competition is more likely to raise consumption (through price or wage changes) rather than lower demand, then output (and employment) will tend to rise. If it is more likely to reduce investment (by lowering profits), then output and employment will fall.

**Network industries, first mover advantages, and superstars affect competition.** Brynjolfsson and McAfee (2014) expand on another dimension of this discussion by focusing on market power captured by first movers. These firms and individuals become “superstars”, being rewarded substantially more than others in the marketplace due to their domination. For example, superstars are the owners/CEOs of companies such as Instagram, or Intuit (TurboTax automated tax preparation), or individuals such as J.K. Rowling. Superstars arise because relative advantage can often lead to “absolute domination” in a market if a company/individual suddenly captures a large market. Such “winner-take-all” markets are more common now because of (a) declines in production and distribution costs due to increasing digitization of goods, services, and information; (b) vastly reduced costs due to improvements
in telecommunications and transportation; and (c) increased importance of networks and standards.

Furman and Orszag (2015) document an increasing differentiation between firms in the same industry, highlighting the importance of large firms in the economy. They contend that a substantial amount of the income inequality in the United States is due to income inequality between firms and not between individuals. For example, similarly educated individuals get much higher different salaries at more productive/ large firms which are more profitable and are dominant in their fields. Labor will move to these firms and overall employment impacts will be determined by how much these firms affect overall output and labor demand or constrain new entry and alternative innovators.

The geography of demand spillovers influences the geography of output and employment effects; flexibility in markets increases employment. Gregory et al (2016) examine the effects of routine labor tasks being replaced due to technological change in Europe. The analysis is conducted for the group as a whole and also separately for 238 European regions. Their methods aim to identify the net effect of innovation on employment, through the direct substitution of capital for labor in tasks, but also the compensating effects operating through product demand and local demand spillovers. They find net positive labor demand across 27 countries over 1999-2010 because sizable substitution effects have been more than compensated by (a) product demand in local markets and (b) its associated spillovers. However, the size of the product demand spillover depends critically on where the gains from the increased productivity of technological capital accrue. RRTC is estimated to have raised labor demand by up to 11.6 million jobs, accounting for half of the total observed employment increase during this period, but this result depends critically on non-wage income feeding back into local product demand. If only wage income is considered, the value falls to 1.9 million jobs.23

23 They build a model that incorporates both direct and indirect effects of innovation and then conduct an empirical analysis. The model assumes, like Dorn and Autor, 2013, that ICT is used in the tradable sector and the nontradable sector uses only labor.
Gregory et al find that the negative impact on labor rises, the more the substitutability between tasks, and the positive impact rises, the more the substitutability in demand.24 Both effects are stronger in regions with a stronger initial share of routine tasks. To the extent that additional income from wages and profits is spent locally, demand for non-tradables rises too. If firm owners are not located in the region or do not spend in the region, the total compensation effect is smaller. The authors caution that even if the net effect on employment is positive in the long run, unemployment can rise in the short run due to factors that constrain overall demand and factor redeployment. For example, there may not be mobility across regions, or across jobs, income earned may not be spent, expectations may hold back production and/or demand, or firms may have more market power, among other things.

In a very recent paper, Autor and Salomons (2017) examine the relationship between productivity growth and employment using country and industry level data for 19 countries25 over a period spanning more than 35 years.26 They find that industry-level employment robustly falls as industry productivity rises, but country-level employment rises with country-level productivity. Both the employment-reducing (in the advancing sectors) and employment-increasing effects of productivity growth (in the spillover sectors) are sizable and the net effect on employment is modest. The size of the employment effects depend on the relative weight of the sectors in the economy, product market competition, demand saturation, and integration in international production chains. They conclude that increases in final demand and inter-industry linkages play an important role in “compensation”.27

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24 If the price of one good falls, there is more demand for it and production rises.
25 The countries are the developed- EU countries minus those in Eastern Europe, the Republic of Korea, among others.
26 Their basic measure is labor productivity but using total factor productivity gives comparable results.
27 They note that the results support the neoclassical story in that both labor supply and final demand jointly determine output and employment. The key driver of employment is the population of consumer-workers.
note that population growth has been an important factor in demand increases, and that spillover effects have fallen in the 2000s.

McKinsey (2017) describes the types of jobs that will change in countries over the world and the impact on overall employment, estimating that China, India, Japan and the United States account for almost two-thirds of the employees whose jobs could be lost by using the full potential of existing technology. World Bank estimates put jobs at risk at 69% in India and 77% in China. Other estimates of job loss across countries abound. McKinsey (2017) also concedes that the rate of take-up of digital technology in each country will vary according to country circumstances (for example, regulation, cost of deployment, complementary skills, finance). The report also concludes that despite these changes, the long run impact on employment opportunities will not be negative: for example, workers will always be needed to complement robots.

Finally, a large literature has found differentiated effects on labor demand by skill type in developed countries. It finds that labor demand falls for tasks that machines can do; these tend to be low and middle skill “rote” jobs. This type of change has been linked to what is referred to as “polarization” or income/wage inequality (see annex).28 These issues are not discussed here, but the Annex provides references to important studies.

More research and knowledge are needed on how the gig economy is affecting the welfare of labor. On the positive side, the new technological revolution is opening up opportunities for entrepreneurs of all ages. Often working part-time, small entrepreneurs, in both developed and developing countries, are proliferating. In many rich countries, the digital revolution has spawned a class

28 To the extent that the demand for low-skilled labor falls more than the demand for highly-skilled labor rises, overall employment will be affected until the market adjusts.
of entrepreneurs that are small in scale and produce highly customized goods and services. The “new” job world is largely composed of artisans and small entrepreneurs producing differentiated and customized goods rather than standardized goods at large scale that machines produce more efficiently. It is also reflecting new tech innovators or would-be innovators in search of their fortunes. Many of these start-ups are sold to (sometimes actively sought by) large, older, established companies rendering the sector even more concentrated. In many poor countries, the digital age has also spawned a new class of small entrepreneurs engaging with the online marketplace. Investments in infrastructure: transport, broadband, energy, logistics, and in education and health will be important if these entrepreneurs are to reap the full benefits of the digital age. Such investments have the potential to increase competition in the sector too. The pace at which this type of activity can replace traditional jobs as well as the pace at which output of old and new products can be increased matter for employment. It is important to better understand the factors that support this pattern of employment.

Globalization and Technology Transfer: Special Features of Developing Countries

In developing countries, technology is mostly transferred from abroad, rather than being homegrown, and it takes the form of embodied technical change. Trade (in goods, services and factors), foreign direct investment and other capital flows influence technology transfer across borders and thus the rate of innovation in countries. Technological change in developing countries (firms), is still mostly imported through trade/FDI/direct technology transfers, rather than the result of R&D (Vivarelli, 2014). Although emerging economies are increasingly becoming innovators in their own right, there is a vast trove of technology that is already available but not adopted at all or by very few producers in developing countries. Technology is transferred by various types of actions by firms and individuals. Foreign firms/ multinationals through trade and FDI import technical know-how; ideas and knowledge flow through the internet; people migrating across borders have taken their know-how with them to host countries. Domestic firms competing with foreign producers adopt new technology to survive.
Country-specific factors affect the type and rate of technology transfer. A host of country-specific elements affect the rate of such transfers and adoption. These are trade policies, the strength of intellectual property protection in host countries, transport costs, the business climate (including finance), finding complementary labor skills at the right price and anything else that affects firm profitability. Policies influencing immigration and capital flows also affect the rate of technology transfer. The final impact on the host country depends on the form in which technology or innovation crosses borders (for example, licensing agreements) as well as the conditions inherent in the country (e.g., on their economic structure, the business climate, how well markets work, human capital and other endowments, or the macroeconomic framework). The paucity of R&D related innovation joined with a high prevalence of institutional barriers preventing “compensation” mechanisms from working effectively in developing and emerging economies (DMEs) means that the net effect of innovation tends to be labor-saving to a larger degree than it is in more developed countries. Box 1 presents a possible scenario for a garment exporting developing country.

So...new technology adoption by MICs today has similar effects on their economies as new technology adoption historically has had on today's advanced economies; lower income countries respond differently. A number of studies examine the impact of innovation (generally in the form of technological adaptation, often through trade) on labor markets in developing countries. These tend to focus on the skill-bias of technological adoption, rather than on overall employment. For example, Almeida (2009) using a firm level data set spanning 8 countries (in the early 2000s) finds that greater openness and technology adoption have increased the demand for skills in MICs. However, for manufacturing firms in China and low-income countries there had been greater specialization in low-skill intensive goods (such as garments in Bangladesh). This skill bias in MICs is consistent with their having...
better initial conditions allowing them to receive more advanced technological innovations than low income countries. It is also consistent with low income countries exploiting their comparative advantage in wages, which has, to date, been substantial enough to prevent displacement of labor in manufacturing. With cheaper automation and digitization, these conditions and patterns may change as discussed in Box 1.

Berman and Machin (2000) examine technology transfer in the manufacturing sectors of 37 high, middle and low-income countries during the 1970s and 1980s. They find rapid skill upgrading in many developing countries with technology diffusion across international borders altering the skill structure of employment of similar industries in different countries. Developing countries were subject to the same transformation in later decades as the U.S. economy was in the 1960s and 1970s (with output and employment growing). There was a migration of technologies from developed to middle income countries, but not to LICs. These past experiences provide support to the presumption that the rate of adoption of technological innovation will vary across countries as will their impact.

Meschi et al (2015), examining the relationship between trade openness, technology adoption and relative demand for skilled labor in the Turkish manufacturing sector during 1980-2001 (using firm-level data in a dynamic panel setting) find that R&D expenditures are positively related to skill upgrading. Moreover, foreign ownership and exporting status raised the demand for skills. Fajnzylber and Fernandes (2009) find that Brazilian firms engaging in imports, exports or FDI exhibit a higher demand for skilled labor, but that Chinese firms engaging in these activities have a lower skilled labor demand than firms that do not. They conclude that international economic activities act as a channel for skill-biased technology diffusion in Brazil, which has a much higher per capita income, but have an effect

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30 This is contrary to the Hecksher-Ohlin-Stolper-Samuelson theorem that would have predicted that Turkey export goods more intensive in unskilled labor. Note that if the assumption of homogenous PFs is relaxed, then international openness-imports, exports, FDI- may facilitate technology diffusion.
of specialization according to comparative advantage in unskilled labor intensive goods in China. They also find that R&D raises the demand for skilled labor. Feenstra and Hanson (2001) find that growth in FDI in Mexico during 1975-88 is positively related with the growth in skilled labor employment. These studies indicate that not all countries will be affected similarly in the short run by the progress of digitization.

What does the transformation in skill demand reveal about employment and income effects in LDCs? Developing countries will fare differently depending on the state of their endowments, specifically human capital. For example, countries where cheap labor was the source of comparative advantage (whether skilled or unskilled) will see their comparative advantage disappearing to the extent that the tasks performed by this labor, ceteris paribus, can be replaced and done more cheaply. Several factors will determine the speed of displacement as discussed above, because the ability of firms to take advantage of the existing new technology and the profitability of firms depend on a slew of factors. As relative labor costs become higher than the alternative of producing with robots, because wages rise or costs of automation fall, then developing countries benefitting in global markets because of cheap wages will see these benefits fall. Trading patterns will change substantially and the benefits of trade will increasingly depend on technological advantage (and there is a chance that those who are behind now will fall further behind). Developing countries must respond to this challenge by maximizing spillover effects.

31 Though skilled labor demand may rise, unskilled labor demand rises more.
32 While international trade facilitates technology diffusion it may also lead to inequality and wage dispersion in these countries. Recent literature finds SBTC through trade to be an important factor in affecting wage dispersion.
**Not all manufacturing is equal: there is nothing magical about labor doing rote tasks in factories.** Employment in manufacturing has traditionally been regarded as an important next step for developing countries diversifying out of agriculture. Higher labor productivity in manufacturing went along with investment and rising labor productivity in agriculture. The concern is that digitization is accelerating the movement towards employment in the services sector—bypassing manufacturing and that this pattern of development will not lead to similar gains for developing countries. Moreover, manufacturing itself requires fewer numbers of workers than previously. As there is nothing magical about doing “rote” tasks, it is incorrect to think of countries that have “missed” the low-skill manufacturing phase as having lost out in the development process. The challenge is to employ them in

| Box 1. Replacing Labor with Machines...what would happen if... |
|-------------------------------------------------------------|
| Suppose new robots are created that can take over all or most tasks of garment production. Suppose that all tasks that humans now perform can be done at a much lower per unit cost by investing in robots. Rich countries that import garments from poor countries with cheap labor will now have comparative advantage in producing garments (I assume that firms have access to finance, can invest in this new technology and have the capacity to use the technology) both for domestic consumption and exports to third countries. Multinationals’ business models will change: they will relocate in their home countries in order to export. (Changes in location will partly be determined by transport costs and trade agreements/restrictions for garments and textiles.) The low wage country will see unemployment and falling wages. If the industry is intensive in female labor, it will see a disproportionate increase in female unemployment. |
| Suppose the market for garments in the low wage country has large and small domestic firms that also produce for export. Now domestic firms may also find it profitable to invest in machines. The larger firms are more likely to have capital to invest in the new technology, while many smaller ones will not. The largest firms will lay off workers and the smaller ones may exit. The larger firms may become more productive, but in developing country markets, there are also less likely to be positive spillovers. Alternatively, even the larger firms may lose their comparative advantage in garment production. In the new scenario, the advantage they will have over rich country exporters will not be lower labor costs or better infrastructure, but perhaps lower transport costs to some destinations or preferential access to markets. The demand for labor, the skill composition of labor employed, the global pattern of production and the global pattern of trade are all likely to change. The social impact of these changes, if uncorrected, could be large. For example, suppose the developing country is Bangladesh whose largest export industry is garments, an industry that employs a large and increasing female labor force. Think of the strides they have made in pulling their families out of poverty. Think of how empowered they felt in society having jobs and wages. |
different high productivity activities rather than solely low-productivity (and thus low wage) service
sector activities and in the higher-skilled manufacturing sectors. Supporting key investments will raise
labor productivity. In the short run (while citizens are being educated), reforms discussed in this paper
are critical in ensuring that some of the low-skill dependent manufacturing goes to or remains in these
countries as they prepare for the future. At the same time, public policy should be supportive of
technology adoption. Constraints to such technology adoption in terms of human capital or other
capacity, the market constraints to maximizing spillover benefits, the institutions and policies to
maximize benefits and the sharing of the profits from such adoption (if not through labor income)33
should be areas of focus.

Policy Space: Sharing the benefits

Policy makers face a number of challenges in the digital age, because innovations34 cause
disruptions that may have substantially negative human impacts in the short run. As tasks are digitized,
people losing income or jobs (or unable to get income or jobs) will need one or both. Being employed is
a “good” for many people that, beyond making leisure possible, also provides intrinsic “self-worth”. Yet,
redistribution from winners to losers is politically complicated in the best of times; it is easier to give
free rein to individual capitalism than to come to a collective decision about what is fair/just and then
implementing policies to achieve fair and just outcomes.

Structural and macroeconomic policies will affect investments and reallocations needed for
output and job growth. The main distributional concern will be how to share the benefits among those
who adopt or produce innovations (e.g. researchers, business, farmers, consumers, people employed in
new sectors) and profit from their sale, and others whose lives are adversely affected by the innovation

33 Note that the production technology used in different countries can vary and they can still export variants of the
“same” good.
34 Even substantially welfare enhancing ones.
(workers moving out of agriculture who may not get jobs). This section deals with two questions: what can policy do to (1) minimize the pain of disruptions to employment, and (2) to increase the chances that employment rises with technological advances. Several suggestions have been made in the literature and these are presented below. Each needs further consideration and development for specific country contexts.

In the first category are policies of the following types: (a) transfers and subsidies to those losing work as a result of innovation; and (b) raising additional resources to finance redistribution to those who have lost jobs. For (a), these are policies such as direct income support or income tax credits to augment low wages, or a minimum income to compensate for unemployment,35 or provision of non-wage benefits that are not linked to employment (e.g. health and pensions). For (b), suggestions include a greater use of Pigouvian taxes (e.g. congestion pricing), taxing rents, and taxing non-labor assets including robots, wealth and profits. For example, Brynjolfsson and McAfee (2014) coining the term the “second machine age”, contend that the peer economy (Airbnb, TaskRabbit) will grow substantially, but the returns to labor in these activities may remain well below what many were earning in previous jobs, so people will need income support in order to have a decent standard of living. Among policies aimed at redistribution, they advocate: (a) providing resources to support those without employment or with low wages. They specifically advocate a negative income tax, a version of which exists in the United States (the Earned Income Tax Credit). They also propose (b) raising resources by redistributive taxation, for example by taxing rents, and using more Pigouvian taxes such as congestion pricing. West (2015) advocates transfers/subsidies as well as some labor market initiatives (see below). Among his proposals are (a) delinking benefits such as health care, disability and pensions from employment; (b) considering

35 At time of writing, Finland has just begun an experiment using basic income support. Under this scheme, the participants all receive a minimum guaranteed income regardless of employment or wealth/income status.
a basic income guarantee, which could be tied to volunteer activities or work requirements; and (c) revamping the EITC by raising the income limit and making cash/refunds available on a monthly basis.

In the second category are the following: (c) labor market adjustments; (d) improving the business and macroeconomic climates; (e) government initiatives to support greater research and development; and (f) public investments in infrastructure and education. Labor market adjustments proposed are those such as lower working hours per person, better bargaining to share rents between employers and the employed, training staff that are unemployed and education for those not yet in the labor force, better search and match mechanisms or policies to change incentives at the firm level (such as labor subsidies or capital taxes). Several years ago, Weiserbs et al (in Bosworth, 1983) discuss mechanisms to improve market solutions. For example, they show that full employment can be maintained by certain labor market initiatives such as distributing labor demand among the whole workforce, cutting hours per worker, or augmenting the number of workers per machine. Though this study was written decades ago, they recommend moving labor to what they termed “unproductive” employment, but is more commonly known as services (such as education for the young, caring for the elderly, revitalizing cities, doing research, artistic endeavors, etc.). Brynjolfsson and McAfee (2014) argue that people must be assisted in finding work to maintain their standard of living. Other policies they support are those that change labor quality and institutions, for example, improving the quality of education, and mechanisms that help match jobs and seekers. Pfeiffer (1997) examines the relationship between employment, skill structure and innovation in East and West German manufacturing firms during 1993-1995, and importantly, he advocates different policies for more poorly developed East

36 A substantial literature is emerging on the human capital needs of the digital age and the role of public policy. This paper does not discuss these initiatives in detail but refers the reader to the burgeoning literature.
37 They quote Voltaire: “Work saves a man from three great evils: boredom, vice and need.”
Germany to what he recommends for more advanced West Germany.\textsuperscript{38} He finds that labor demand drops in response to modernization in both East and West Germany, the response being stronger in East Germany which had a lower-skill labor force. He believes that to support low-skill employment in the less sophisticated East German system, \textit{labor subsidies} were a more effective instrument than was subsidizing R&D and investment.\textsuperscript{39} Spiezia and Vivarelli (2000) also describe how technological unemployment can be avoided through labor market regulations. These adjustments include a progressive reduction of the per capita annual working time, as has occurred dramatically in Europe.\textsuperscript{40} Among labor market incentives, West (2015) advocates (a) providing activity accounts for lifetime learning and job retraining (citing France as an example of a country that has individual activity accounts for social purposes); (b) providing Incentives and work credits for volunteerism; (c) doing curricular reform with more learning focused on communication, collaboration and teamwork, and ability to think critically; and (d) expanding arts and culture for leisure time. He also advocates encouraging corporate profit sharing. Citigroup (2016), includes suggestions such as retraining, adding income to wages, reducing the cost of labor, and helping workers to find employment. Looking at previous episodes of innovation induced unemployment, Perez (1983) and Pasinetti (1981) point to safety nets, a reduction in working hours, or various union strategies as responses to process innovation. To support employment, Mandel and Swanson (2017) note the importance of education.

\textsuperscript{38} He finds complex patterns of substitution between capital and labor in the two parts of Germany, justifying his choices on a number of factors, such as differences in wage setting behavior, initial skill levels, firm type and economic environment.

\textsuperscript{39} He differentiates among three types of labor costs with varying degrees of flexibility and importance for workers of different skill types: (a) those determined by government such as payments to the social transfer system, or minimum wages; (b) those determined mainly by firms, such as pensions and fringe benefits (though there may be mandated benefits) and (c) those determined by negotiation between unions and employers, such as wages, holidays, and working times. The percentage of labor costs determined by each category varies by skill; high-skilled workers have more in category (b) relative to others and these are the categories that governments tend to have more power to transform.

\textsuperscript{40} Keynes already mentioned this as a possibility.
Measures to improve the business climate and macroeconomic environment are critical in sharing the benefits of innovation. Policy suggestions are aimed at fostering more competition in markets so that the gains from innovation are not captured by a select few. Examples of such policies are: adapting the strength of intellectual property regimes, using competition policy to ensure that innovation is encouraged, and market liberalization to support competition, financial sector development to increase funding of innovation/entrepreneurship, improving infrastructure to support private investment, supporting aggregate demand through stimulatory macroeconomic policy, particularly if actual output is lower than (the new) potential output resulting from innovation. Among these papers, Brnjolffsson and AcAffee (2014) suggest a number of measures for startups such as reducing regulation for ease of entry, growth and exit, facilitating immigration to ensure an increasing supply of highly skilled workers, reducing IPR protection to reduce the share of profits captured by innovators and increase the share accruing to consumers and (potentially) smaller/newer producers, and upgrading infrastructure to support innovation, its commercialization, and access to services. Perez (1983) and Pasinetti (1981) examining earlier decades of technological disruption, contend that the institutional setting of IPR regimes substantially affected market responses after innovation. Strong IPR enforcement could change the balance between R&D and ETC in order to induce more innovation; at the same time, overly strong IPR systems could limit the forces of competition in markets and thus inhibit compensation effects from fully playing out.41

Mandel and Swanson (2017) suggest a number of measures to maximize the employment effects of innovation and technological adaptation. Though their paper is focused on the U.S. economy, the lessons are generally applicable. They find that even in the United States, the full benefits of

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41 There is a large literature on the impact of IPR regimes on growth and technology adoption. World Bank (2002), World Development Report, and World Bank (2005) provide good summaries of the literature and evidence, along with policy recommendations.
digitization have yet to be felt. Most sectors of economic activity will continue to benefit from
digitization for some time yet and the potential for output growth is huge over the medium term. For
the business climate, Mandel and Swanson (2017) support lower corporate tax rates to support
innovation and job creation and allowing immediate expensing of capital investment. They recommend
the use of trade policy to break down non-tariff trade barriers to encourage competition but advocate
stronger IP protection for innovators, using the two policies together to manage competition while
supporting innovation. Finally, arguing that new technology requires a new regulatory framework, they
recommend a regulatory framework that encourages experimentation and promotes entrepreneurial
ventures, particularly in the health care industry. However, they are not specific as to the type of
regulation that needs to be replaced. They also make a case for publicly supported infrastructure
investment, particularly in 5G wireless, fiber optics, cloud computing, software and IoT sensor networks.
They contend that such investments, supported by the public sector, will allow the complex
technologies to spread in all sectors and demand for -properly trained- labor because ultimately, these
technologies will need to be guided by human labor.

Particular features of financial markets are found to support R&D. Mann (2017), studying U.S.
firms, finds that patents are used as collateral for significant debt financing. In 2013, 38% of U.S.
patenting firms had pledged their patents as collateral and these firms then subsequently raised their
R&D activities. They therefore advocate strengthening creditor rights to facilitate using patents as
collateral. Hochberg et al (2014) find that intensified patent trading increases the annual rate of startup
lending, particularly for firms with less firm-specific patent assets.42 43 Governments should directly
support innovation funding by complementing the activities of private VC firms. If the new gig economy

42 Kerr and Nanda (2014) have an excellent overview of this literature.
43 Samila and Sorenson (2011) examine the rise of VC firms and their impact on entrepreneurship in the United
States during 1993-2002. They find that the local supply of VC firms positively affects the number of new firm
starts, employment and aggregate income.
is to prosper and create employment, funding for growth will be critical. A growing literature on financing for innovation finds that mature and new innovators rely on different sources of finance, and government can support entrepreneurship by providing innovation finance. Lerner (1999) examines the effect of federal funding to small businesses in the high tech sector in the United States and finds that even in the United States, which has the highest degree of VC funding, government funding matters. Firms funded by government tended to do well if they were in areas where there was already significant venture capital funding of firms. In fact, government funding was an effective complement to innovation but did not provide additional encouragement when private VC activity was not substantial.\textsuperscript{44} Howell (2014), examining similar subsidies to energy firms, finds that a government award increases patenting activity and also doubles the probability of subsequent VC funding. She concludes that the financing is important, but that the receipt of an award reveals relevant and otherwise unattainable information about the firm, and thus encourages private funding.\textsuperscript{45}

\textit{Macroeconomic and structural policies} to support output growth are discussed in Piacentini and Pini in Vivarelli and Pianta (2000). They point to demand growth as an important factor in influencing the employment effect of innovation. If output growth falls short of the rate of increase in labor productivity, aggregate unemployment can increase. They point out that innovation driven supply shocks resulting in lower labor demand affect both average wages and their distribution. Both of these changes affect individual demand and may result in lower private aggregate demand, at least in the short run. The macroeconomic consequences of lower consumption (or investment) in the “transition”

\textsuperscript{44} The author contends that government funding may help reduce the risk of funding and may help fill gaps for entrepreneurs. VC activity also helps monitor firms.

\textsuperscript{45} Tsu, Tian and Xu (2014), examining data from 32 developed and emerging economies, find that there is more innovation in high-tech industries in countries that have more developed equity markets. The development of credit markets does not have similar effects, as high-tech firms tend to have intangible assets and banks are inherently more risk averse and seek tangible collateral.
could have long term effects and would work against “compensation” bearing fruit. They argue that sustainable employment growth will be possible when demand accompanies supply potential and that public policy can play an important role in this regard. Another way to think of the period after an economy-wide, productivity-enhancing innovation is as a period during which potential output (traditionally defined as the level of full employment output) has increased. As current output depends on the current state of aggregate demand, the situation prevailing after innovation resembles the Keynesian problem of deficient demand. A period of Keynesian deficient demand can correct itself when demand expands endogenously as a result of technical innovation and market adjustment (Hussain in Bosworth 1983) or could need some policy support. Note that while output is less than potential, expansionary policy will not raise inflation. At the new level of potential output, labor intensity of output will be lower, but overall employment can still be higher.

Pianta (in Vivarelli and Pianta (2000)) and Pianta (2004) contend that macroeconomic policy and performance can support product innovation and employment growth and may offset labor reductions resulting from process innovations. Together with appropriate regulation or competition policy, good macroeconomic performance supports investment and strengthens “compensation” effects. The conclusion is that conditions constraining demand growth vary across time and countries. If the shock to employment and demand is considered a temporary negative shock, in some situations, fiscal policy may be an appropriate tool to support transition to the new full employment level of output and employment. Perez (1983) and Pasinetti (1981) recognize the importance of institutional changes in supporting demand and market flexibility, contending that innovation will be more expansionary in the right policy and institutional (e.g. regulatory and organizational) environment. In a downturn, these settings are critical to maintaining consumption and therefore aggregate demand and output.

*Direct support to innovation and innovators* is an important policy. Mandel and Swanson (2017) contend that direct public and private funding of R&D as well as providing incentives for R&D in the
private sector remain top priorities for policy. In a recent paper done for “Innovate UK”, the Technology Strategy Board of the UK government, Mazzucato (2014) advocates an activist role for government in supporting innovation in the economy. The paper argues that the government needs to forge strong public-private partnerships and play an active role (financial and otherwise) in research and innovation in order to support inclusive growth. They argue that government should be proactive on the direction of change, share funding, and share the risks and rewards of innovation. Brynholfssen and McAfee (2014) support federal funding of basic research to complement private sector R&D. Pfeiffer (1997) in his study of unemployment in West and East Germany, contends that measures to support R&D (including financing of it) and increased public investment were good policy choices for supporting employment growth over the medium-term in West Germany, which had well-functioning markets and institutions (though not in East Germany, where markets did not function well). In well-functioning markets, (where resource reallocation is easier, and financial sectors are developed), public investment will complement private investment, public support to research will be more likely to spawn innovation and both will support output growth to bolster labor demand.

These studies highlight a number of areas in which policy will need to come together to provide a holistic response to digitization-labor interactions. These policies and their impacts, for example a universal basic income, labor subsidies, government financing of entrepreneurship, incentives to provide for basic R&D, among others, remain to be further studied for application in specific country contexts.

**Demographics and Technology: Aging and Shrinking Labor versus Labor-Saving Technology**

Finally, a word on demographics. Much of the developed world (and even some of the emerging/developing world) faces aging and/or shrinking populations, a phenomenon that has raised concern about how to maintain output growth in many countries. For example, EU studies on demographics and growth highlighted the need to find alternative ways to maintain output and growth
in the face of declining, as well as aging, populations. As a result, there is a drive to increase labor force
participation rates and retrain older workers to increase their productivity. Neither of these mechanisms
will raise labor supply indefinitely. Other countries are pointing to the exodus of workers. The
interaction of the challenges posed by demographic shifts and migration with those posed by the
adoption of labor-saving digital technologies has not been fully explored. On the one hand, a simple
analysis would conclude that when the labor supply falls, income can grow when machines are found
that replace labor, capital or other resources. Thus, countries seeing large scale outmigration can
potentially preserve GDP per capita growth by substituting machines/AI for labor. 46 In fact, recent
papers by Acemoglu and Restrepo (2017), using a sample of 49 countries, find that countries undergoing
rapid aging have not grown less than others that have not. The authors find more rapid adoption of
automation technologies (particularly industrial robots) in countries undergoing more rapid
demographic changes. 47

The issue is more complex if the labor that is lost cannot be replaced by machines, and it is also
more complex if the labor that is left cannot work with machines. In the former context, certain labor
types will be scarce and there will conceivably be a change in what the country produces (or migration
to remedy the scarcity). In the second case, education/training is a solution. For example, the older labor
force is less likely to be working in technology heavy contexts, and they may need “training” to do so; at
the same time, machines could be made that complement older peoples’ skills and raise productivity of

46 This assumes that the conditions for replacing humans with machines, for example access to finance, IPRs etc.,
are in place.
47 Acemoglu (2010) and Acemoglu and Restrepo (2016) demonstrate that the scarcity of younger and middle-aged
labor can trigger sufficient adoption of robots (and other automation technologies) so as to actually increase
aggregate output.
the existing workforce. In a recent study, McKinsey (2017) contends that the impact of aging and the loss of labor in many economies will more than balance the increase in labor-saving hours.

There are also countries where the labor force is not expected to decline in the near future, and there is a large share of young unemployed people; neither is the population expected to age fast. These are developing countries in the Middle East, Africa and parts of Asia, for example. Yet, to the extent that younger populations are more educated and entrepreneurial with skills to complement machines, the greater will be their advantages. In these countries, it will be critically important to ensure that compensation mechanisms work and that the gig economy and entrepreneurial activity are supported. Still, in all this, an important question remains unanswered: what are the actual employment and earnings in the proliferating gig economy? For example, how much has net income/welfare increased because of Uber or TaskRabbit, and what is the distribution of this income? What age or ethnic group is benefitting most from these activities and which groups are left out? Are people who are engaging in the gig economy mostly those who previously had no jobs and no (health and other) insurance, or are they displaced workers who have lost “regular” jobs and associated benefits? Are these patterns changing from year to year as the number of services grows? These are some of the important (for policy) questions that need further research.

Conclusion

For some years now, researchers have been studying the effect of innovation, particularly digitization (including automation), on employment and remuneration. This paper reviews the market mechanisms that translate innovation into job growth or loss and policies under discussion to manage these effects. What do these studies imply about the economic effects on developing countries as

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48 For the first time, there are reportedly a larger number of elderly workers employed in the Republic of Korea than young ones. Also, an increasing number of entrepreneurs are over 50.
49 Education and workforce preparation is not discussed here.
technological innovation spreads? Using historical experience coupled with the fast spread of digital technology across borders as guides, the compelling story is that there will be large changes on production structures and labor markets in developing countries. The precise nature of these changes is hard to imagine as the impact of digital technologies is fast transforming work in ways that could not have been imagined. The other part of the story is that developing countries are behind advanced nations in the technological frontier and thus have much to gain in terms of productivity growth by adopting existing technologies. While they may no longer face the transition from agriculture to higher productivity manufacturing, they will now face the transition to high productivity services. The adjustment story, in terms of who adopts technology and how fast, and who faces more severe labor market disruptions will vary substantially across nations. The gig economy is growing fast, yet much more study is needed to understand the employment and income effects of the gig economy in various sectors and countries. More study is also needed on the links between changes in population such as aging or reductions in size and automation.

Moving towards a socially acceptable distribution of the gains from innovation or even determining what this might be, is much harder in policy making than is facilitating efficiency in decentralized, profit maximizing markets. The key distributional question is how much innovators should keep and how much they should share with society, particularly when inequality rises. The policy maker’s role is more complex the more concentrated are the gains from innovation and the faster changes are promulgated.

Policy has a significant role in managing the human costs of disruptions to economic activity, even if the long-term benefits are substantial for most people, in ensuring that compensation mechanisms can play out fully and that society as a whole benefits from innovations. Macroeconomic, social and structural policies can influence the growth and distributional impact of innovation. The policies necessary to reap the full benefits of innovation at acceptable distributions of income/wealth
span a wide range of areas. The specific package most suited to a country will depend on its context, including societal preferences. The policies discussed in the literature can be grouped broadly into following categories, as presented in this paper: (a) transfers, insurance and subsidies to those losing work as a result of innovation; (b) raising additional resources (and rationalizing expenditures) in order to finance redistribution to those who have lost jobs; (c) labor market adjustments, including regulatory ones; (d) improving the business climate to support more effective resource reallocation and firm growth, (e) supportive macroeconomic climates; (f) developing financial markets to support innovation; and (g) government initiatives to support greater research and development. Some general conclusions regarding the direction that policy must take in order to minimize the disruptions to employment and income as employment opportunities change follow.

Fiscal redistribution and insurance mechanisms are needed to support those who lose jobs as a result of innovation. They are also needed to support entrepreneurs who have no income support. One of the arguments for the universal basic income is that it provides a minimum survival wage for everyone, which serves the dual purpose of encouraging entrepreneurship and ensuring basic needs. Arguments for de-linking social insurance (health and pensions) from formal employment hinge on the benefits arising from the flexibility afforded labor, but also the provision of basic needs. As the nature of employment and the nature of the firm itself change, existing fiscal systems may bear more pressure from both the revenue and expenditure sides. For any country to deliver a feasible plan for the digitization age, as outlined in this paper, fiscal restructuring and rationalization of systems are needed.

Changing relative prices resulting from digitization are already beginning to have an impact on global production patterns and this trend is likely to continue. Developing economies will lose existing sources of comparative advantage faster than previously envisaged. For example, low-wage manufacturing may be more expensive than automated production, once the initial investment in automation is done. In these cases, production taking advantage of low wages may relocate to where
the investment in technology is easier. Global value chains may be restructured significantly with
digitization. The previous pattern of development, where emerging countries grew by expanding
manufacturing exports that used relatively lower wage labor, may no longer be a viable path; instead
developing countries will develop by replacing manufacturing by higher (than previous) productivity
services. The best option for public policy in developing countries is facilitating the adoption of relevant
technology (not just digital technology) by firms and enabling entrepreneurial activity. Unequal access to
technology (whether it be high yielding seeds, a modern tractor, pesticide application with drones, or
the use of the internet for market price information, to name a few) within countries will raise inequality
further. Developing countries, already suffering from high productivity dispersion between firms, but
poor resource reallocation abilities, will be hit particularly hard.

In the adoption of technology, and in facilitating entrepreneurship more generally, finance plays
a very important role. In the more traditional form of technology adoption (embodied technical change),
investment goods obtained with credit can serve as collateral-if domestic systems are sufficiently
developed. However, obtaining credit can be particularly hard for creative ventures where there is high
risk and little in the way of collateral. In countries where patents can be enforced, patents can serve as
collateral. A number of countries are experimenting with equity financing by venture capitalists; these
types of initiatives are important. For all these types of financing sources to succeed, supportive public
policy, regulation and supervision are needed. Studies in the United States have shown that public seed
funding for innovative projects can also support entrepreneurship, though the success of these ventures
is more visible when they operate alongside private venture capital funds (so that the two inform each
other, rather than displace each other). Not all types of interventions will be suitable for all countries.
Policy makers need to be creative in thinking about how financial systems can be supported so that (a)
new technology can be adopted, and (b) innovation (creating) is supported.
Providing incentives for current and potential innovators to produce is a complex balancing act for policy makers. Innovators—be they individuals or firms—aim to maximize the market profits of their innovations. IPR’s granting (temporary) monopoly power to the innovator, is one form of protection granted by government. The strength of IPRs determines how effective they are in preventing entry in markets and thereby deterring competition. Stronger IPRs encourage others to innovate, knowing that they can capture the benefits of their creations. However, there is a downside to overly stringent IPR systems because competition in markets serves at least three additional purposes: (a) competition is itself a force for innovation and excessive monopoly power may reduce innovation, and companies competing against each other in markets regularly innovate in products and processes; (b) it increases efficiency; and (c) it allows consumers a greater share of the benefits from innovation. In addition, restricting adoption of the new technology may serve to reduce growth. Policy has to balance these competing influences. Eventually society gains when the productivity gains, low prices, or new goods are passed on to consumers. Some innovations do not require patents for the innovator to capture gains, but many first movers (particularly in large fixed cost or network industries) capture the gains by virtue of the type of market in which they operate. Policy makers need to support contestability in markets (for the same reasons as above), but they need to avoid taxing the technology (e.g. use of robots), instead simply taxing rents to pay for needed redistributions. Public policy needs to be carefully designed and adapted to suit particular circumstances. Trade and FDI agreements are particularly important for cross border transfer of technology.

As in the market for goods and services, both competition and collaboration have distinct roles in the market for ideas. Large private corporations tend to have greater financial resources to support research and the development of new ideas. Competition in the market for ideas is good. Public policy should support research and development through other measures such as tax exemptions, and direct provision or funding of R&D. The objective would be to invest directly in areas where the private sector
is unlikely to do so (or is likely to underinvest), to collaborate with the private sector, and to support R&D in smaller or finance-constrained private entities (see above) so they can compete in the market.

Demand growth is necessary if jobs are to accompany innovation that is labor-saving. Thus, the importance of supportive macroeconomic environments for investment, including new profit reinvestment, sharing productivity gains through lower prices, and facilitating business entry and exit. New products and services have been the most important factors offsetting the employment-reducing effects of labor-saving technology at the macroeconomic level. If technology raises the potential level of output, then a policy environment that supports movement to this higher output is desirable. Basic infrastructure provision, and infrastructure supporting the development of digitization (broadband, 5G wireless networks) are areas where government involvement, and public-private ventures can bear fruit and help move the gig economy towards being a sustainable source of income.

Finally, and very importantly, education/training, including re-skilling of workers, is a core ingredient of the labor adjustment process. Given the large literature that already exists and more that is fast being produced, this paper has not reviewed the nature of educational changes that would be required for the digitization age. Governments, companies and households around the world are aware of the challenges they face in this regard. Public and private initiatives to support education of the current and future workforce are needed. Human capital is indeed the key to a better life with higher income.
The impact of innovation on labor by skill type: substantial evidence on skills and wages

Innovation in history has affected the types of labor demanded as well as the quantity. The early stages of the industrial revolution in the United Kingdom and the United States, for example, were accompanied by an increase in the relative demand for skilled labor. Gray et al (2013) discuss how the electrification of factories - electricity being a general-purpose technology, as is computerization- caused a “hollowing out” of the skill distribution in manufacturing, similar to that of computerization in the present day. Goldin and Katz (1996-1998) find skill upgrading due to computerization during 1940-1996 in the United States.Autor et al (1998) examine the effect of SBTC (as measured by computerization) on the widening of U.S. educational wage differentials during 1940-1996, indicating changes in labor demand relative to labor supply. In Autor et al (2003), they explicitly model and empirically investigate the impact of technology on the skill content of jobs. Translating task shifts into education demand, their model explains 60% of the estimated relative demand shift favoring college labor during 1970-1998. An analysis of the progress of machines and its impact on the skill composition of the U.S. workforce (MacCrory et al, 2014) during 2006-2014 finds a significant reduction in the demand for skills that compete with machines-mostly middle and low skill jobs- and an increase in labor demand where machines are not used. They contend that these changes in labor demand have contributed to increasing inequality. Looking at more recent years, Katz and Margo (2013) and Gray (2013) find that rapid skill upgrading within detailed industries accounts for most of the growth in the relative demand for college workers, particularly since 1970. They use this to explain wage inequality and educational wage differentials.
Michaels et al (2010), using industry-level data for the United States, Japan, and nine European countries during 1980-2004, find that digitization has made labor markets more “polarized”, with employment in the middle of the skill distribution falling relative to the top and, in recent years, relative also to the bottom of the skill distribution. Industries with faster growth of ICT have greater increases in relative demand for highly educated workers and bigger falls in relative demand for middle educated workers. Wages are affected too. The United Kingdom had the highest increase in the high-skilled wage bill share (16.5 pp) and the largest increase in ICT intensity. The United States had the second largest growth of ICT and the third largest increase in the high-skilled wage bill share (13.9 pp). Goos et al (2009) using data on 16 European countries for 1993-2006 find job polarization (growth in employment at the highest and lowest skills) for Europe as a whole (pooled data), but also for almost all 16 countries in their sample. Akcomak et al (2013), in a study of the United Kingdom and the Netherlands during 1997-2006, find job polarization due to both Skill-Biased Technological Change (SBTC) and offshoring, but conclude that the former is more important in both countries. Importantly, they find that within job task content has changed too due to SBTC. Sabadash (2013) and EC (2012a) find that favorable dynamics in labor productivity boosted by ICT innovations have not been associated with similar adjustments in real wages. Wages, particularly of low-skilled workers, lag behind. They contend that institutional and distribution systems play an important role in shaping the causal links between productivity, wages, demand for final goods, and employment.

Autor and Salomons (2017) show that despite the relative neutrality of productivity growth for aggregate labor demand, productivity growth in primary and secondary industries has generated a

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50 Trade openness is also associated with polarization, but this is not robust to inclusion of technology. They do also say that trade may increase technology adoption; see also Draca et al 2009, on this.

51 Note that wage inequality is not necessarily correlated with the share of low wage income. If a country for some reason has a high share of employment in low-wage occupations, then this may tend to raise inequality. The relationship may not run from wage inequality to low-wage employment.
substantial reallocation of workers into tertiary services. These services have a comparatively bimodal skill distribution of employment, so labor demand has been “polarizing” with the effect on high skills being much stronger than that on low skills though. Along with other studies, the authors also highlight how digital technology is accelerating the movement of employment from manufacturing into tertiary sectors.

References

Acemoglu, D and P Restrepo (2016) “The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment” NBER Working Paper No. 22252.

Almeida, R. (2009). Openness and technological innovation in East Asia: Have they increased the demand for skills? IZA Discussion Papers, 4474, Bonn.

Acemoglu, D and P Restrepo (2017), “Secular Stagnation? The Effect of Aging on Economic Growth in the Age of Automation” NBER Working Paper No. 23077

Alvarez, R., Benavente, J.M., Campusano, R., Cuevas, C. 2011. Employment Generation, Firm Size, and Innovation in Chile. Technical Notes, No. IDB-TN-319, Inter-American Development Bank, Washington, DC.

Antonucci, Tommaso and Mario Pianta (2002), “Employment Effects of Product and Process Innovation in Europe”, International Review of Applied Economics, vol. 16, issue 3, 295-307.

Autor, David and Anna Salomon (2017), “Does Productivity Growth Threaten Employment”, Paper prepared for ECB Forum.

Autor, David, David Dorn, Lawrence F. Katz, Christina Patterson, John van Reenen (2017), “The Fall of the Labor Share and the Rise of Superstar Firms”, NBER working paper, No. 23396.

Barkai, Simcha. 2017. “Declining Labor and Capital Shares.” University of Chicago. Accessed May 30, 2017. http://home.uchicago.edu/~barkai/doc/BarkaiDecliningLaborCapital.pdf.

Benavente, Jose Miguel and Rodolfo Lauterbach (2008), “Technological Innovation and Employment: complements or substitutes?”, The European Journal of Development Research, vol 20, issue 2, pg. 318-329.

Benedikt Frey, Carl, and Michael Osborne. 2015. “Technology At Work: The Future of Innovation and Employment.” Citi GPS (Global Perspectives & Solutions), February 2015. Accessed June 29, 2017. http://www.oxfordmartin.ox.ac.uk/downloads/reports/Citi_GPS_Technology_Work.pdf.
Berman, Eli and Stephen Machin, 2000, “Skill-Based Technology Transfer around the World”, *Oxford Review of Economic Policy*, vol. 16, issue 3, 12-22.

Brynjolfsson, Erik, and Andrew McAfee. 2014. *The Second Machine Age*. New York: W. W. Norton & Company.

Citi GPS (2016), “Technology at Work v2. The future is not what it used to be”, *Oxford Martin School and Citigroup, Citi GPD, Global Perspectives and Solutions*.

Conte, A., and M. Vivarelli. 2005. “One or Many Knowledge Production Functions? Mapping Innovative Activity Using Microdata.” IZA Discussion Paper 1878. Bonn, Germany: IZA. Conte, A., Vivarelli,

De Loecker, Jan and Jan Eeckhout, 2017, “The Rise of Market Power and the Macroeconomic Implications”, *NBER Working Paper* No. 23687.

Dobbs, Ian M., Martyn B. Hill, and Michael Waterson. 1987 “Industrial Structure and the Employment Consequences of Technical Change.” *Oxford Economic Papers* 39(3): 552-567.

Döttling, R., Gutiérrez, G. and Philippon, T. (2017), “Is there an investment gap in advanced economies? If so, why?”, forthcoming in ECB, *Investment and Growth in Advanced Economies*, Frankfurt am Main

Evangelista, Rinaldo. 2000. “Innovation and Employment in Services: Results from the Italian Innovation Survey.” In *The Employment Impact of Innovation*, edited by Marco Vivarelli and Mario Pianta, 121-148. London and New York: Routledge.

Evangelista, Rinaldo and Maria Savona, 2002, The Impact of Innovation on Employment in Services: Evidence from Italy, International Review of Applied Economics, 16:3, 309-318, DOI: 10.1080/02692170210136136.

Fajnzylber, Pablo and Ana Fernandes, 2009. “International Economic Activities and Skilled Labor Demand: Evidence from Brazil and China. *Applied Economics*, vol. 41, issue 5, 563-577.

Feenstra, Robert and Gordon Hanson, 2001, “Global Production Sharing and Rising Inequality: A survey of Trade and Wages. *NBER Working Paper*, no. 8372.

Furman, Jason, and Peter Orszag, 2015. “A Firm-Level Perspective on the Role of Rents in the Rise in Inequality.” Paper presented at Columbia University’s “A Just Society” Centennial Event in Honor of Joseph Stiglitz, New York, NY.

Furman, Jason 2016, “Beyond Antitrust: The Role of Competition Policy in Promoting Inclusive Growth “Jason Furman Chairman, Council of Economic Advisers Searle Center Conference on Antitrust Economics and Competition Policy Chicago, IL September 16, 2016

Greenan, Nathalie and Dominique Guellac, 2000. “Technological Innovation and Employment Reallocation”, *Review of Labor Economics and Industrial Relations*, vol. 14, issue 4, 547-590.
Goos, Maarten, Alan Manning, and Anna Salomons. 2009. “Job Polarization in Europe.” *American Economic Review* 99(2): 58-63.

Gray, Rowena. 2013. “Taking Technology to Task: The Skill Content of Technological Change in Early Twentieth Century United States.” *Explorations in Economic History* 50: 351-367.

Gregory, Terry, Anna Salomons, and Ulrich Zierahn. 2016. “Racing With or Against the Machine? Evidence from Europe.” ZEW Discussion Paper No. 16-053.

Harrison, Rupert, Jordi Jaumandreu, Jacques Mairesse, and Bettina Peters. 2014. “Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparable Microdata from four European Countries.” *International Journal of Industrial Organisation*, 35.pg. 29-43.

Hesselman, Linda, and Ruth Spellman. 1983. “Responses to the Employment Consequences of Technological Change.” In *The Employment Consequences of Technological Change*, edited by Derek L. Bosworth, 189-207. New York: Holmes & Meier.

Hochberg, Yael, Carlos Serrano and Rosemarie Ziedonis, 2017, “Patent Collateral, Investor Commitment and the Market for Venture Lending, [http://yael-hochberg.com/assets/portfolio/HSZ.pdf](http://yael-hochberg.com/assets/portfolio/HSZ.pdf)

Howell, S. (2014). Financing constraints as barriers to innovation: Evidence from R&D grants to energy startups. Working paper.

Hsu, P.H., Tian, X., & Xu, Y. (2014). Financial development and innovation: Cross-country evidence. *Journal of Financial Economics*, 112(1), 116-135.

Hussain, Athar. 1983. “Theoretical Approaches to the Effects of Technical Change on Unemployment.” In *The Employment Consequences of Technological Change*, edited by Derek L. Bosworth, 13-24. New York: Holmes & Meier.

James, Bernard. 1983. “The Trade Union Response to New Technology.” In *The Employment Consequences of Technological Change*, edited by Derek L. Bosworth, 174-188. New York: Holmes & Meier.

Karaomerlioglu, Dilek Cetindamar, and Hacer K. Ansal. 2000. “Innovation and Employment in Developing Countries.” In *The Employment Impact of Innovation*, edited by Marco Vivarelli and Mario Pianta, 165-181. London and New York: Routledge.

Katz, Lawrence F., and Robert A. Margo. 2013. “Technical Change and the Relative Demand for Skilled Labor: The United States in Historical Perspective.” NBER Working Paper No. 18752. Cambridge MA: NBER.

Lee, Sangheon, Deirdre McCann and John C. Messenger, (2007), “Working Time Around the World”, Trends in working hours, laws and policies in a global comparative perspective. Routledge Studies in the Modern World Economy, ILO, Geneva.
Lerner, Josh, 1996, “The Government as Venture Capitalist: The Long-Run Effects of the SBIR Program,” *NBER working paper No. 5753*.

MacCrory, Frank, George Westerman, Yousef Alhammadi, and Erik Brynjolfsson. 2014. “Racing With and Against the Machine: Changes in Occupational Skill Composition in an Era of Rapid Technological Advance.” Research paper for Thirty Fifth International Conference on Information Systems, Auckland 2014.

Maddison, Angus, 1991, Dynamic Forces in Capitalist Development, *Oxford University Press*, Oxford.

Mandel, Michael and Bret Swanson, 2017. “The Coming Productivity Boom: Transforming the Physical Economy with Information”, *techceocouncil.org*.

Mann, Willam, 2017, “Creditor Rights and Innovation: Evidence from Patent Collateral”, *UCLA Anderson school of Management*.

McKinsey & Co. (2017), “Technology, Jobs and the Future of Work”, *McKinsey*.

Meschi, Elena, Erol Taymaz and Marco Vivarelli, 2016. "Globalization, technological change and labor demand: a firm-level analysis for Turkey," *Review of World Economics* (Weltwirtschaftliches Archiv), Springer; Institut für Weltwirtschaft (Kiel Institute for the World Economy), vol. 152(4), pages 655-680, November.

Michaels, Guy, Ashwini Natraj, and John Van Reenen. 2010. “Has ICT Polarized Skill Demand? Evidence from Eleven Countries Over 25 Years.” *NBER Working Paper No. 16138*. Cambridge MA: NBER.

Parisi, M.L., Schiantarelli, F., Sembenelli, A., 2006. ‘Productivity, innovation and R&D: Micro evidence for Italy,’ *European Economic Review*, 50, 2037-2061.

Pasinetti, Luigi, (1981). “Structural Change and Economic Growth”. Cambridge University Press, Cambridge.

Perez, Carlota (1983), ‘Structural Change and the Assimilation of New Technologies in the Economic and Social Systems’, *Futures*, Vol. 15, No. 5, pp. 357–75

Pianta, Mario. 2000. “The Employment Impact of Product and Process Innovations.” In *The Employment Impact of Innovation*, edited by Marco Vivarelli and Mario Pianta, 77-95. London and New York: Routledge.

Pianta, M. 2004. Innovation and Employment, in Fagerberg, J., Mowery, D. and Nelson, R. (eds), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford, chap. 21.

Pfeiffer, Friedhelm, 1997, “Human Capital and Innovation in East and West-German Manufacturing Firms“, *ZEW Discussion Paper No. 97-08*, Mannheim.

Placentini, Paolo, and Paolo Pini. 2000. “Growth and Employment: Productivity Gains versus Demand Constraints.” In *The Employment Impact of Innovation*, edited by Marco Vivarelli and Mario Pianta, 44-76. London and New York: Routledge.
Plümper, Thomas, and Vera E. Troeger. 2004. “The Estimation of Time-Invariant Variables in Panel Analysis with Unit Fixed Effects.” University of Essex.

Sabadash, Anna. 2013. “ICT-induced Technological Progress and Employment: a Happy Marriage or a Dangerous Liaison? A Literature Review.” JRC Technical Reports, Institute for Prospective Technological Studies Digital Economy Working Paper 2013/07. Luxembourg: Publication Office of the European Union.

Samila, Sampsa and Olav Sorenson, 2011, “Venture Capital, Entrepreneurship, and Economic Growth” Review of Economics and Statistics, Volume 93 | Issue 1 | February 2011 p.338-349

Simonetti, Roberto, Karl Taylor, and Marco Vivarelli. 2000. “Modelling the Employment Impact of Innovation: Do Compensation Mechanisms Work?” In The Employment Impact of Innovation, edited by Marco Vivarelli and Mario Pianta, 26-43. London and New York: Routledge.

Spiezia, V., Vivarelli, M., 2000. The analysis of technological change and employment. Pg.12-25 in Vivarelli, M., and M. Pianta, (Eds.), The Employment Impact of Innovation:Evidence and Policy, Routledge: London.

Massimiliano Tancioni & Roberto Simonetti, 2002. "A Macroeconometric Model for the Analysis of the Impact of Technological Change and Trade on Employment," Journal of Interdisciplinary Economics, vol. 13(1-3), pages 185-221, January.

Vivarelli, Marco. 2014. “Innovation, Employment and Skills in Advanced and Developing Countries: A Survey of Economic Literature.” Journal of Economic Issues 48(1): 123-154.

Weiserbs, Daniel, A. Kervyn, and Alan Ingham. 1983. “Employment Policy for Balanced Growth under an Input Constraint.” In The Employment Consequences of Technological Change, edited by Derek L. Bosworth, 66-81. New York: Holmes & Meier.

Zimmermann, Klaus. 1991 “The Employment Consequences of Technological Advance: Demand and Labor Costs in 16 German Industries.” Empirical Economics 16(2): 253-266.