GROUP OF TWENTY

Future of Work: Measurement and Policy Challenges

Prepared by Staff of the
INTERNATIONAL MONETARY FUND*

* Does not necessarily reflect the views of the IMF Executive Board.

EXECUTIVE SUMMARY

The new technologies hold promises but also significant challenges. Advances in digitalization, artificial intelligence, and automation promise to raise productivity and growth, but they are also bound to reshape the economy and the way we work, with the potential to increase inequality. Given the dimension of the possible changes, it will take a comprehensive and coordinated policy response to secure growth that is widely shared. These policies will also raise challenges for public finances.

A better understanding of the changes afoot is critical. Coverage of the new digital economy in the national accounts and labor statistics is incomplete, introducing some inaccuracy into productivity measures and complicating the monitoring of ongoing structural changes such as the growth of new forms of work organized around digital platforms. Closing these data gaps is essential to better understand, observe, and ultimately meet the challenges ahead.

Policymakers should facilitate technological change, smooth adjustment and ensure that gains are equally shared, while updating policy frameworks where needed (see Table 1).

- *Facilitate technological advances*. To realize the potential increase in productivity, policies should balance encouraging competition and incentivizing innovation. Labor and product market reforms, digital infrastructure investment, and economic integration can foster technological diffusion and the efficient reallocation of resources.
- *Support adjustment while preserving inclusiveness*. Active labor market policies and safety nets can protect workers while allowing change; and the tax/benefit system can help ensure that growth is broadly shared. Education is key to meet the demand for more flexible skill sets and lifelong learning, especially for the most negatively affected. Where taxes need to rise to finance higher spending, their impact on growth and income distribution should be assessed.
- *Updating policy frameworks is another critical objective*. Social safety nets and pension insurance systems will need to adjust to increasing cross-country mobility and more fragmented work careers against the background of pre-existing trends such aging and lengthening working lives. The new technologies also bring challenges for the public finances, as they foster hard-to-tax activities while creating evolving spending needs.

There is a significant international dimension to these efforts. Given that many of the expected policy challenges occur simultaneously across countries, there is a strong case for sharing information and best practices. In addition, there are areas where international cooperation is a must—including coordination of competition policy around multinational firms operating in the new economy and taxation.

The best policy approach will vary across countries. Even though all countries have reason to move quickly to close data gaps and implement reforms to facilitate growth, the need to smooth the adjustment depends on the speed at which the new technologies impact the economy. In addition, well-designed structural reforms should consider countries' economic starting conditions—including their institutional setup, income level, and conjunctural environment.

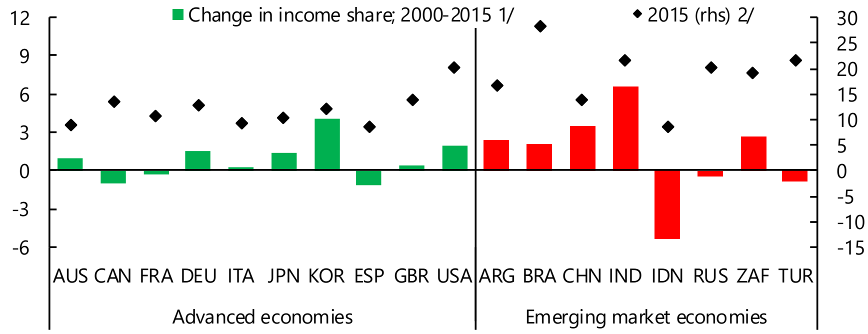
Produced under the supervision of Helge Berger and Romain Duval by a team including Esteban Vesperoni (lead), John Bluedorn (RES), Margaux MacDonald (RES), and Marshall Reinsdorf (STA), with additional contributions and support from Aqib Aslam (FAD), Pankhuri Dutt (RES), Csaba Feher (FAD), Maura Francese (FAD), Svitlana Maslova (SPR), Adrian Peralta Alva (FAD), and Ilse Peirtsegaele (RES). David Coady, Ruud De Mooij, Rupa Duttagupta and Catherine Pattillo provided additional guidance.

CONTENTS

ACKNOWLEDGING THE CHALLENGES: FACILITATING CHANGE AND SUPPORTING THE ADJUSTMENT

1. **Technological advances are reshaping the economy and the future of work, and may spur profound changes and difficult policy tradeoffs going forward.** New technologies—such as digitalization, artificial intelligence, and automation—have the potential to change the nature of production processes, raise productivity, and reshape labor markets. However, as their development is happening at a time of sluggish growth in real wages and productivity and a falling share of labor in national income, it is raising anxiety about the future of work. Their widespread adoption may involve costs incurred by way of labor displacement and adjustment, rising inequality, job and wage polarization, and social instability. This would come against a backdrop of already rising top income shares and broader measures of inequality (Figure 1). As most periods of technological disruption in the past, this tradeoff between aggregate income gains and transitional and distributional costs is bound to raise significant challenges (Mokyr and others, 2015; IMF, 2018a). Addressing them requires first understanding the role of technology in shaping new production processes, with the concomitant changes in terms of productivity and labor market relationships.

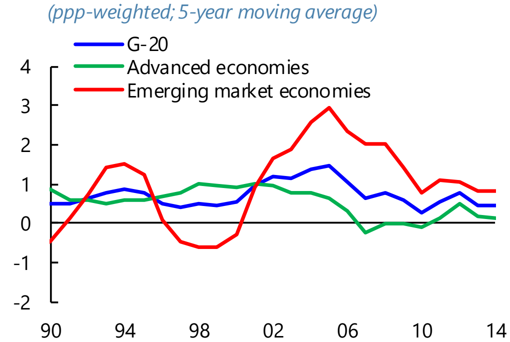
Figure 1. G-20 top 1 percent income share
(percent)



Sources: World Top Incomes Database; and IMF staff calculations.
1/ Change in income share is in percentage points. Earliest data for DEU and BRA is from 2001 and ZAF and TUR is from 2002.
2/ Latest data for ARG and IDN is from 2004; ITA from 2009; CAN and JPN from 2010; DEU from 2011; KOR, ESP, and ZAF from 2012; IND from 2013; and AUS, FRA GBR and USA from 2014. MEX and SAU are not included due to data limitations.

2. **Assessing the current and future impact of new technologies is a complex task.** In light of the fast pace of technological progress in recent years, the lasting decline in productivity growth in many G-20 countries may seem puzzling (Figure 2). In part, this slowdown reflects scars from the 2008-2009 global financial crisis—such as persistently low investment amid economic slack, elevated uncertainty and, in some cases, weak banking systems (IMF, 2017a, Adler and others, 2017)—that are now dissipating. However, productivity growth has bounced back only modestly so far, consistent with widespread evidence that some of the slowdown has been structural. Several causes for this have been explored. A widely held view is that there

Figure 2. G-20 total factor productivity growth 1/
(ppp-weighted; 5-year moving average)



Sources: IMF, *World Economic Outlook* July 2017 Update; Penn World Tables (PWT); and IMF staff calculations.
1/ SAU and RUS are not included due to data limitations.

may be a lag in the realization of the new technologies' true productive efficiencies (Brynjolfsson, Rock and Syverson, 2017). Indeed, many of the technological advances, such as artificial intelligence, have yet to spread widely in most industries—automated transportation, for example—and, if the past in any guide, productivity gains likely will require a gradual reorganization of production before they become fully effective (David, 19990). Another view is that these technologies, together with other factors, might be driving a rise in market power in advanced economies which, if strong enough, might limit the widespread adoption of technology and the incentives to innovate (Diez, Leigh, and Tambunlertchai, 2018). An aging workforce may also be slowing productivity growth, which could explain the more acute and earlier decline in advanced economies compared to emerging markets. Finally, it has also been argued that the productivity growth slowdown may be milder than currently measured (Ahmad, Ribarsky, and Reinsdorf, 2017).

3. **The impact on labor markets is no less uncertain, but is likely to involve major changes to both the types of jobs and the nature of worker-firm relationships.** In advanced G-20 countries, regular contracts remain predominant, and in many emerging G-20 countries labor market informality remains pervasive. But work forms are changing, particularly in advanced countries, where an increasing share of the population is employed (either part time or full) in independent work intermediated by digital platforms or in other new occupations that have emerged along with new technologies (Autor and Dorn, 2013; Acemoglu and Restrepo, 2016; Katz and Krueger, 2016). At the same time, many jobs—particularly those involving low- and middle-skill routine tasks—are being eliminated through labor-saving automation and artificial intelligence (AI). This comes against a background of existing challenges, which may differ among countries—including the fact that advanced countries must meet the demands of an aging workforce, while several emerging economies require boosting job creation for the youth and addressing the challenge of informality.

4. **These complexities suggest that accurate measurement to assess the tradeoffs from technological changes is critical.** Policymakers need a clear understanding of the trends in production and labor markets if they are to steer the response to the challenges ahead. However, coverage of the digital economy in the national accounts and the ongoing changes in the labor market statistics are incomplete. This suggests two key areas for improvement: The first is productivity statistics, for which the main issue is accuracy. There are gaps in measuring digital platforms and outsourced services, and quality adjustment in deflators is limited. This can lead to underestimated productivity growth and should be corrected. The second area is labor market statistics, where the main concern is lack of information. Existing labor market surveys are not capturing the digital economy well. This hampers the accounting of aggregate employment statistics and limits understanding of the gig economy—new work forms centered around tasks and the help of digital platforms, often outside traditional employment contracts—which despite its current modest size is growing rapidly.

5. **Informed by a reliable assessment, policies to facilitate technological change and smooth the adjustment can be better designed.** Depending on societies' preferences—notably regarding sharing the burden of adjustment and income distribution—policies can support a smooth transition through the changes shaped by new technologies. These policies should respond to three key objectives.

- The first one is to *facilitate technological advances* with reforms that unleash their potential productivity boost. The necessary reforms cut across multiple areas—including product and labor markets, patent protection, public and private investment, and international integration—with two over-arching goals: supporting market competition while balancing incentives for innovation; and facilitating technological diffusion and the sectoral reallocation of capital and labor.
- A second objective is to *support inclusiveness in labor markets during the adjustment process*. Disruptions can be smoothed in the short run through redistributive and active labor market policies, and in the longer run through education and other human capital-augmenting investments.
- Finally, *updating policy frameworks* is another critical objective. This will require ensuring that countries' social protection—that is, safety nets and social insurance—and tax/benefit systems are in line with the challenges ahead. Some of the necessary actions will require additional analysis and consideration, while others will have to be taken upfront given the adjustment lags involved—pension reforms, for example. In a number of areas, there is scope and need for international cooperation, reflecting the fact that the opportunities and challenges associated with technological change transcend borders.

6. These three key objectives involve policy synergies. For example, well-targeted human capital investment will serve both technology diffusion and labor market inclusiveness objectives. Likewise, easing formal job protections while strengthening social safety nets can both facilitate productivity-enhancing labor reallocation and help workers cope better with future labor market disruptions.

7. The best policy approach will vary across countries. Even though all countries have reason to move quickly to close data gaps and implement reforms to facilitate growth, the need to smooth the adjustment depends on the speed at which the new technologies impact the economy. In addition, well-designed structural reforms should consider countries' economic starting conditions—including their institutional setup, income level, and conjunctural environment. Finally, the available fiscal policy space matters, especially when the envisaged policies come with higher spending needs.

8. The rest of the note is organized as follows. Section 2 examines the statistical challenges and list recommendations to address measuring issues on productivity and labor market dynamics. Section 3 proposes policies to facilitate possible transitions in the workplace and frames a broad discussion of national policy options and the gains from international policy coordination. Section 4 discuss specific country needs and the timing of policies.

UNDERSTANDING THE CHALLENGES: MEASURING PRODUCTIVITY AND LABOR MARKET DYNAMICS

9. Fostering the benefits of new technologies requires good measures of their impact, notably on productivity growth and labor market developments. The depth and speed of future technological advancement and its impact on jobs and production processes are largely unknown. Ensuring accurate measurement is thus critical in reducing this uncertainty. Yet, as discussed in the introduction, technological advances have created measurement challenges and new data needs in many areas of economic statistics, notably on two issues: productivity measures and employment. This section will tackle these in turn.

A. Technology and the Measurement of Productivity

10. The issues in measuring productivity involve both compilation methods and the conceptual framework. The compilation issues include challenges adjusting prices for quality changes in the products included in the price index baskets and including new products and suppliers in the composition of the basket and in GDP. Conceptual issues are related to the role of data as an asset, the treatment of free services supplied by digital platforms and the impact of new inventions. Finally, there are also difficulties in measuring productivity at the sectoral and country levels associated with the role of digital technologies in facilitating the growth of outsourcing and of globalized production processes. Improvements in compilation and measurement (such as enhanced price indices for existing goods and more timely incorporation of new goods), as well as in conceptual frameworks, will help measure more accurately productivity growth and its underlying drivers.

Is Productivity Growth Mismeasured for Compilation Reasons?

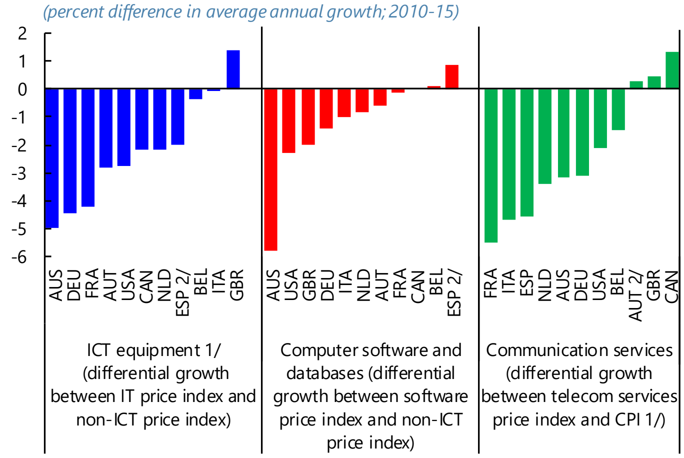
11. Productivity growth may be underestimated because of inadequate adjustments for quality change of products in the price index baskets and lags in updating the latter to include new products. Productivity growth equals the difference between (real) output and inputs growth—labor in the case of labor productivity, or labor and capital combined in the case of total factor productivity (TFP). Challenges in constructing the deflators for information and communications technology (ICT) goods and services could cause growth of output and capital inputs to be underestimated. Researchers have frequently found evidence of under-adjustment for quality change in the official price indexes, and advances in technology mean that the quality changes tend to be positive in the case of ICT products. Another source of measurement error in deflators is lags in including new digital products in the price index, which may result in price declines being missed early in the life of these products.

12. Some research suggests that changes in ICT prices have been overstated due to inadequate quality adjustments. The size of the overstatement has been inferred from quality-adjusted price indexes constructed in specific country studies based on microdata, and from cross-country comparisons of national deflators:

- *Country-specific Studies*. In the United States, researchers have constructed quality-adjusted price indexes for many ICT products; Byrne and Corrado (2017a and 2017b) find an overstatement of about 6 percentage points in the growth rate of the official deflator for ICT investment in 2008-2015 and 6.8 percentage points for household digital equipment in 2005-2015. In the United Kingdom, a research index for telecommunication services implies that the official deflator overstated the price growth rate by 7 percentage points in 2010-2015 (Abdiraham and others, 2017).[1]

- *Cross-country Studies*. Country comparisons of price indexes for ICT equipment, software, and communication services find a wide range of prices changes, even after controlling for differences in general inflation (Figure 3). This is somewhat puzzling, especially in the case of ICT equipment, for which international trade should prevent large price differences between countries. Differences in measurement procedures seem to be the most plausible explanation. If the national indexes with the higher growth rates are under-adjusting for quality change, a typical overstatement of the price growth rate for ICT equipment and communication services is in the range of 2-4 percentage points. For software, the typical overstatement is somewhat lower, between 1 and 3 percentage points.[2]

Figure 3. Difference between ICT and non-ICT price index
(percent difference in average annual growth; 2010-15)



Source: Ahmad, Ribarsky, and Reinsdorf, 2017.
1/ ICT = information and communications technology. CPI = consumer price index.
2/ Data reported for Spain for ICT equipment and computer software and database correspond to 2010–14. Data reported for Austria for communications services correspond to 2011–15.

13. Price changes may also be overstated when online and sharing economy suppliers replace traditional suppliers. Deflators usually fail to capture the reductions in prices paid when households change suppliers—for example, a sharing economy supplier like Uber may be cheaper than a taxi. This occurs both because of the procedures used to bring new suppliers into the index, and because e-commerce and sharing economy prices tend to be under-represented or omitted from

[1] The authors also experiment with an approach based on spending per byte of data transmitted. This approach implies a much larger bias but rests on the—rather strong—assumption that all bytes of data are equally valuable.

[2] In many economies, ICT products are largely imported. In this case, the effects of overestimation of prices changes for imports and consumption would approximately offset each other.

the samples used to compile the indexes.[3] Nonetheless, the combined effects on the productivity growth rate are likely to be small—the spending that migrates in a given year to new online and sharing economy suppliers is likely to represent a small share of household spending and, in the case of online shopping, the price differentials are modest (for example, Cavallo (2017) finds that Amazon's prices are, on average, just 5 percent lower than offline prices).

14. Overall, the overstatement of the growth rate of ICT prices has an impact on productivity measurement, albeit a modest one. The average share of production of ICT equipment and software and communications services on value added in OECD countries reached 5.4 percent in 2015, with only two countries significantly over 6 percent.[4] Excluding the communication services used by other businesses—which do not affect measurement of aggregate productivity—the average weight of the affected products in the productivity calculations may be about 5 percent. Thus, an overstatement of 6 percentage points in the price growth rate of ICT equipment, software, and communications services would cause an understatement of labor productivity growth of 0.3 percentage points. Effects on TFP would be much smaller, as correcting the growth rates of ICT equipment and software would make inputs of capital services grow faster.[5]

15. Compilation problems are another possible factor affecting estimates of nominal GDP, leading to understatement of output growth and productivity. In economies where internet-based activities typically associated with digital platforms (i.e., businesses whose operations are exclusively or primarily online) have grown rapidly, the source data used to compile nominal output may omit startups engaged in new types of businesses linked to the internet. This would result in an understatement of the nominal GDP growth rate, with an associated impact on the growth rate of real GDP, at least in the short term. If only the output is omitted, productivity growth will be underestimated as well—although estimates suggest that the plausible scale of the underestimation of the productivity growth rate is but a few basis points. However, if the associated inputs are also missed—as is likely in the case of omitted sharing economy suppliers—the impact on productivity measurement could be zero, or even positive.[6]

[3] An IMF-OECD survey of price index compilation practices found that most advanced economies collect at least some e-commerce prices and that only three countries collect sharing economy prices. Procedures that would miss the price savings from substitution to e-commerce or sharing economy suppliers are commonly used. See Reinsdorf and Quirós (2018) and Ylä-Jarkko Berry and Stanger (2018).

[4] OECD (2017) Table 3.2.

[5] In the case of the United States, calculations using detailed weights and quality-adjusted indexes are consistent with these estimates. The indexes for ICT equipment and software in Byrne, Fernald, and Reinsdorf (2016) imply an understatement of 0.19 percentage points in labor productivity growth in 2004-2014. Allowing for additional effects from communication services, and assuming a slightly larger measurement error for software would increase the implied understatement to 0.3 percentage points.

[6] The sharing economy comprises platform-enable services.

Is Productivity Growth Mismeasured for Conceptual Reasons?

16. It has been argued that the way GDP is defined causes the growth statistics to leave out the welfare gains from free services supplied by digital platforms. This conceptual issue is mainly related to two potential sources of mismeasurement. One is free media and search provided by digital platforms such as Facebook, YouTube, or Google, which are funded by advertising (and, indirectly collection of user data). Another one is welfare gains from services that consumers produce for themselves using the internet. For example, the internet has enabled consumers to be their own travel agent and to make free long-distance phone calls.

17. The conceptual relevance of the welfare from free services for growth and productivity statistics is unclear. GDP is a measure of production, not welfare, and productivity statistics aim at measuring the performance of business in producing output sold in markets. Redefining productivity to have a mixed measurement objective would muddy its interpretation and potentially obscure important developments affecting questions such as income growth, international competitiveness, and inflationary pressures. Moreover, the impact of the possible refinements to the treatment of free media funded by advertising has been found to be immaterial.[7]

18. Measurement of the level shift in welfare from major inventions such as the Internet requires strong assumptions. If welfare level shifts could be measured in a reproducible way and were deemed relevant for growth, this would only affect the picture of long-run growth and long-run average productivity change; and of the growth rate and productivity change at the time of the appearance of the invention, but not in subsequent years.[8]

Other Implications of Digitalization for Productivity Measurement

19. Digital technologies have facilitated the growth of outsourcing and globalized production processes, affecting labor productivity measures at the sector/industry level. Fort (2017) finds that digital technologies have facilitated fragmentation of the production process and substitution of both locally and globally outsourced services for labor inputs. Measures of labor productivity growth at the industry level based on gross output—i.e., value added plus intermediate inputs—overstate the productivity gains if outsourcing replaces directly employed labor. However, measures of labor productivity based on value added per hour are less susceptible to this distortion, and should be highlighted in the data that is disseminated on industry level productivity.

20. There are also implications for the measurement of productivity at the country level. Fragmented production processes and relocations of intellectual property assets have enabled multinational enterprises (MNEs) to attribute income to specific locations based on tax considerations. This may result in MNEs overstating their production in low tax jurisdictions and understating it in high tax jurisdictions, with corresponding effects on productivity statistics. Some of the proposed

[7] See Nakamura, Soloveichik, and Samuels (2017) and Ahmad, Ribarsky, and Reinsdorf (2017).

[8] For example, the widespread diffusion and adoption of the internet has likely accelerated productivity growth in the late 1990s and early 2000s, and could plausibly be linked to unmeasured welfare gains. However, gains associated to it are unlikely to play a role in the recent productivity slowdown.

solutions to distortions involving relocation of intellectual property assets would attribute the production linked to the intellectual property of a foreign affiliate of an MNEs to the parent or the location where the research and development was produced. However, implementing this solution would require international data sharing that currently is not possible.

Recommendations to Improve Productivity Measurement

21. While the productivity measurement biases introduced by deflators for ICT goods and services may not necessarily be large, there is scope to improve quality adjustment and survey data:

- *Quality Adjustment.* To improve the price indexes for ICT goods and services, quality adjustment procedures should be used more extensively, and the existing procedures must embody up-to-date assumptions and parameter estimates.
- *Updating baskets.* Delays in incorporating new products and new product varieties in price index baskets and samples should be shortened.
- *Surveys for GDP statistics*. Ensuring that survey data used to compile GDP includes new businesses and products in fast-growing digital platforms and platform-enabled services may require special procedures to update the samples and products. Moreover, survey totals must be compared with totals from tax and other administrative data, which will require that policymakers grant statistical agencies access to these data.

B. Technology and Employment Statistics

22. Challenges to understand labor market developments arise from the potential impact of new technologies on employment arrangements, and on the occupational and sectoral distribution of employment. For example, technologies such as digitalization create new work opportunities by reducing transactions costs and expanding some types of production, but they may also eliminate jobs through labor-saving automation. This will likely trigger sectoral reallocation—oftentimes to sectors that are not well-covered by existing statistics. This section first considers the measurement of independent work intermediated by digital platforms. Then it turns to the impact of the replacement of human labor by robots and AI.

Independent Work Intermediated by Digital Platforms

23. Digital platforms have fostered transactions by individuals in online marketplaces. E-commerce platforms for marketing goods have given individuals a new channel to sell things that they have produced—which constitutes self-employment in a micro-enterprise, as the individuals typically decide the price of the output and manage other aspects of production.[9] For labor markets,

[9] In the U.S., a 2016 survey by the Pew Research Center found that four percent of adults engage in online micro-enterprise activity in the past year. In China, Alibaba's digital marketplaces accommodated 10 million enterprises with 5 or fewer employees in 2016 (Cheng, 2017).

so-called gig economy platforms have given individuals opportunities to earn income by supplying labor services—either digitally or physically—in an on-demand or short-term basis.

24. The gig economy is hard to measure, but the number of participants is large and official statistics may be underestimating its size in income terms (Box 1). Household labor market surveys typically lack specific questions about work in the gig economy, and there is evidence that respondents underreport their platform-based work when asked. As a consequence, aggregate estimates of employment and labor income may thus not capture the size of the sector.

25. The gig economy may have cross-border effects on employment. By changing outsourcing practices, work facilitated through these platforms may relocate employment between advanced and emerging economies. In major outsourcing platforms (Upwork), the employers are predominately in advanced economies, while the workers are predominantly in emerging market and developing economies (Horton, Kerr and Stanton, 2017). At the same time, however, new platforms can also reduce labor demand in emerging economies—for example, LiveOps and other call center platforms have enabled independent workers in the U.S. to replace offshore call center services (Scheiber, 2017). The net effect of these developments is difficult to gauge without better statistics.

Recommendations to Improve Measurement of the Gig Economy

26. Given the rapid growth of the gig economy, improvements of its coverage in official statistics are critical. Undermeasurement of the gig economy is likely affecting aggregate employment estimates in some economies. Furthermore, statistics on the size, income and characteristics of gig economy workers are needed to address policy issues associated with the changing nature of work, worker earnings, and social protection coverage. Understanding these issues will require new data, which ideally should be collected in a systematic way that is comparable across countries. There are a number of critical areas that require attention:

- *Refinement of employment surveys*. Household surveys that probe for gig economy activities should be developed to obtain information on the characteristics of the workforce—including estimates of total income. For example, questions like those introduced by the U.S. Bureau of Labor Statistics regarding work and pay from mobile app or web-enabled tasks or jobs, to be incorporated in the fall 2018 survey release, can improve measures of the gig economy. The operators of the gig economy platforms should also be surveyed regularly to develop estimates of the size and pay rates of the workforce, and spending on different types of gig economy services.

- *Tax data*. Statistical agencies must have access to tax and other administrative data—at least in summary form—to obtain estimates of participants and earnings from the gig economy.

- *Private sector data*. Payment agents used by gig economy platforms should also be considered as potential suppliers of source data. These include agents that specialize in paying gig economy workers, such as Payoneer, and general payment agents, such as PayPal and local mobile money operators.

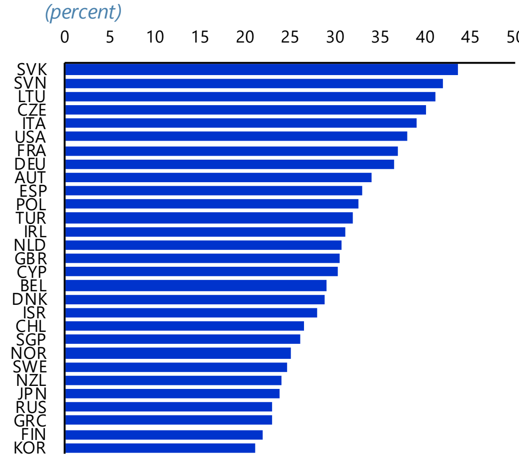
- *Data compilation*. Data will be critical for research on the broad impact of the gig economy on employment and working conditions—for example, whether the gig economy is really displacing wage-and-salary employment or having negative effects on worker earnings and access to social protection.[10] Without additional information, the net effect remains unclear.

27. Data on individuals selling products in digital marketplaces and on contingent work in general would help to put the growth of the gig economy in context. The growth of the gig economy is part of the general growth of non-standard work arrangements.[11] In this context, the distinction between gig economy platforms and temporary staffing agencies is starting to blur, as the latter are deploying digital technology to compete with the former.

The Role of Automation and AI in Job Displacement

28. It has been argued that new technologies will replace a broad range of jobs and create new forms of work, but their potential impact is difficult to predict. Recent analysis by the McKinsey Global Institute suggests that 15 percent of global jobs could be displaced by automation by 2030, with larger potential impacts in advanced economies. Another analysis by Hawksworth, Berriman and Goel (2018) estimates that automation can potentially replace more than 30 percent of jobs in most OECD countries by 2030 (Figure 4).[12] However, these estimates of potential impacts consider only technical feasibility. The gross jobs losses to robotization and AI are likely to be smaller than the proportion of jobs that would be technically feasible to replace. Furthermore, the job losses may be offset by new work opportunities created by technology and by output expansions made possible by falling costs and prices. Indeed, an increase in robot density in manufacturing in Japan has been associated with higher productivity and local gains in employment and wages (Schneider, Hong, and Le, 2018).

Figure 4. Potential jobs at high risk of automation
(percent)



Sources: Hawksworth, Berriman, and Goel, 2018; and *PIAAC data*, PwC analysis.

[10] An analysis of e-commerce in the U.S. illustrates some of the pitfalls in determining net employment impacts. Official statistics on changes in full-time equivalent (FTE) retail employment imply that more FTEs were lost to competition from e-commerce than they were created in retail e-commerce. This may be related to the fact that some e-commerce jobs are classified in the warehouse industry or the temporary help industry. Including these jobs shows that the net impact on employment as measured by FTEs is positive (Mandel, 2017).

[11] For example, Katz and Krueger, 2016, find that the share of workers with non-standard work arrangements in the U.S. grew from 10.7 percent of the workforce in 2005 to 15.8 percent in 2015.

[12] Looking specifically at the European Union, Chiacchio, Petropoulus and Pichler (2018) find that one additional robot per thousand workersworker reduces the employment rate by 0.2 percent.

29. Appropriate measures of the potential impact on jobs are hampered by significant gaps in existing statistics on technology and jobs. Mitchell and Brynjolffson (2017) highlight the lack of data on the scope and growth of AI, and on how technology is eliminating and transforming certain types of jobs. Also, occupational classifications may be challenged to keep up with effects of changing technology and lack detailed information on skill requirements (Djumalieva, Lima and Sleeman, 2018).

30. Managing the potential impact of new technologies in labor markets will require a better understanding of the demand for worker retraining and continuing education, and of the outcomes. The jobs created by automation, and those that survive, will be more demanding in terms of technical skills and cognitive and social abilities than the jobs they replace. Statistics on workforce skills and demands for skills implied by changing occupational employment patterns will be needed to understand the potentially widening gap between workers' skills and competencies and those that employers demand. Data on the experience of graduates of retraining programs could also aid in understanding demands for skills.

Recommendations to Improve the Understanding of the Impact of Automation and AI

31. The challenges of automation and artificial intelligence will require better data on both technological advances and information-processing skills of the population:

- *Technological advances*. Indexes of technology and AI need to be developed to measure advances in technical capabilities, the adoption of advanced technology, and the factors impeding it—such as shortages of labor with needed skills (National Academies of Sciences, 2017).
- *Information-processing skills*. Data collected in the OECD's Program for the International Assessment of Adult Competencies (PIAAC) can help identify mismatches between worker skills and employer needs, and to monitor general education and training weaknesses. Furthermore, updated classifications of occupations—including descriptions of specialized skills and typical tasks—would help inform educators and students about career options and preparedness. These occupational descriptions can be combined with data from the technology and AI indices to identify emerging occupational opportunities and risks, and provide early warning on threatened jobs.

32. Information on employers' demands for skills from non-standard sources should be integrated with statistics from household and employer surveys. An example of this is Burning Glass Technologies, a software developer that uses AI techniques to produce real time indicators of labor market skills mismatches and career path prospects by analyzing online job postings and career-transition information. Another example is the Netherlands' Center for Big Data Statistics, which has used web scraping and text mining techniques to identify and characterize innovative companies.

33. Data on in-demand skills and retraining outcomes can help to guide education curricula. Surveys of skills utilization by those who have completed the retraining programs could be used to identify skills to prioritize. Data on effectiveness of worker retraining strategies could include job placement outcomes that would be used for real time decision making. Understanding factors affecting success in worker re-deployment may also require data on displaced workers' broader circumstances, such as barriers to geographic mobility.

DEALING WITH THE CHALLENGES: POLICY

34. Economic policy should facilitate the new technologies' potential while addressing the challenges that that they may bring. Specifically, policies should (i) make it easier for new technologies to raise productivity and GDP growth; (ii) support adjustments in labor markets to ensure that these gains are broadly shared and workers are protected through technology-induced transitions; and (iii) update policy frameworks to confront potential challenges associated with structural reallocation, a faster depreciation of human capital, and changes in the length and nature of worker-firm relationships. This section tackles these issues in turn.

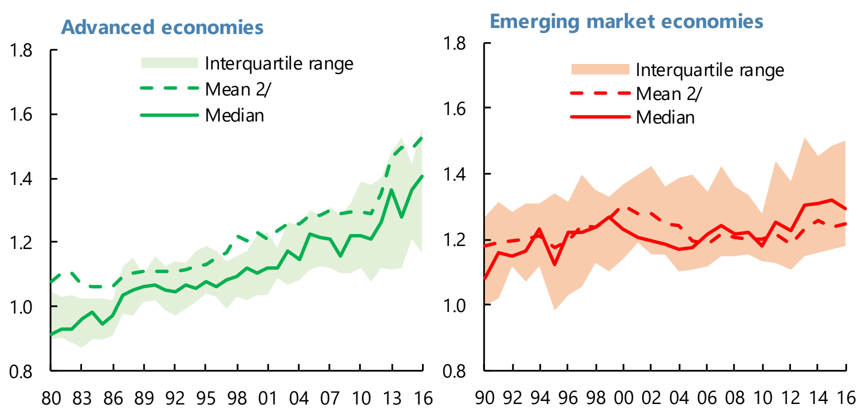
A. Policies to Facilitate Technological Advances

35. Armed with a better understanding of the ongoing challenges, the right policies will raise productivity by fostering innovation and encouraging its diffusion. Policies will involve a mix of structural reforms to product market regulation and labor market institutions, patent protections for substantive innovations, public and private investment to ensure broad participation by producers and consumers, and internationally integrated and open markets. They should focus on two critical objectives: supporting market competition while balancing incentives for innovation; and facilitating technological diffusion and the sectoral reallocation of capital and labor. The note delves deeper into the policies to support these two objectives below.

Competition and Innovation

36. Market competition has been declining globally since the 1980s. Drawing upon an analysis of data for listed firms, Figure 5 exhibits a trend rise in markups (price over marginal cost), a common measure of a firm's market power, across advanced G-20 economies. The increase is broad-based, evident across and even within sectors—although it is larger in ICT-using industries—with the emergence of so-called superstar firms that can command high markups (Díez, Leigh, and Tambunlertchai 2018). However, the reasons for the rise in markups remain

Figure 5. G-20 trends in markups 1/



Source: Díez, Leigh, and Tambunlertchai, 2018.
1/ Markup index shown. The markup is defined as the ratio of the output price to the cost of goods per unit output. Underlying data are at the listed firm-level.
2/ Mean is the country GDP-weighted average.

unclear. For example, network effects can generate winner-take-all markets as incumbents leverage their first-mover advantage and push down competition (Guellec and Paunov, 2017). Alternatively, if the intensity of antitrust enforcement has declined or the cost of starting a business has risen, then these too could decrease competition (Gutiérrez and Philippon, 2017). Regardless of the drivers, strong pro-competition policies can increase efficiency and thereby productivity.

37. **While competition can increase efficiency, its impact on innovation is less clear-cut.** In markets where firms' productivity levels and innovative capacities are similar—so-called neck-and-neck industries that can be found in many advanced G-20 countries—increased competition can spur innovation by firms, as it may alleviate otherwise rising pressures on their profitability. By contrast, if a market is already competitive and productivity levels are dispersed with many firms far behind the productivity frontier, greater competition could dissuade laggard firms from innovation, since expected profits from it would be weaker. Aghion and others (2005; 2009) bring these two channels together and argue that there is an inverted U-shape relationship between competition and innovation. At relatively low levels of competition, greater competition may drive innovation, but at relatively high levels of competition, further increases may discourage it.

38. **To achieve both greater competition and innovation, product market reforms should be complemented by strong intellectual property rights.** Reforms reduce barriers to market entry/exit and the costs of starting a business, improving the efficiency of existing firms and the allocation of resources, expanding the variety and quality of existing goods and services with positive spillovers beyond the deregulated industries themselves, and lowering prices to consumers (see e.g. IMF, 2016a). However, the inverted-U relationship discussed above suggests that their impact on innovation is ambiguous, depending on the extent of neck-and-neck competition, which is difficult to assess with precision. By ensuring that time-limited rights to monopoly profits over the use of innovations in exchange for public dissemination of their design are granted, well-designed patent regimes can provide incentives to innovate even in highly competitive markets (Aghion, Akcigit, and Howitt, 2014). Moreover, patents can facilitate technological diffusion and spark innovation that builds on the database of patented designs. Unlike restrictions to product market competition, which give incumbent firms monopoly profits *ex ante*, strong patent rights have the advantage of rewarding innovation *ex post*, only if it takes place.

39. **Competition and innovation may also be enhanced through improved access to finance, where digital technologies—fintech—have a growing role to play.** On top of the direct efficiency gains for the financial sector, these technologies can boost financing through better risk management, improved identification of productive projects, and new investment and payment options. This may benefit particularly innovative young firms that may otherwise struggle to access finance due to lack of collateral and track record. Recent innovations include blockchains, distributed ledgers, smart contracts, speedier cross-border payment and exchange systems, peer-to-peer lending, and crowdfunding equity investments (OECD, 2015b; IMF, 2017). The increasing use of these technologies, though, should be coupled with a strengthening of regulatory oversight over financial activities to safeguard financial stability, as new risks may surface. Financial digitalization trends heighten the need for cybersecurity to protect financial consumers and producers.

40. The priorities for product market reforms and the best way to implement them depend on country-specific circumstances. In general, product market reforms require little in terms of fiscal resources and their short-term impact depends less on the economy's cyclical position than other structural measures (Duval and Furceri, 2018). However, they generally take time to pay off, and their effectiveness in boosting productivity over the long term depends on the level of economic and financial development. For example, in economies already at the technological frontier, greater trade openness and public investments in education and research may be more growth-enhancing than in economies that are far from the frontier (Aghion and others, 2015). Where state-owned enterprises dominate, opening the market to new entrants promises significant efficiency gains, including in the incumbent firms themselves (Gal and Hijzen, 2016).

Technological Diffusion and Factor Reallocation

41. Broad access to high-quality digital infrastructure is key to promote technological adoption and diffusion. This requires a comprehensive, reliable, and secure digital infrastructure, including high bandwidth broadband, wireless networks, and mobile and landline telecommunications networks (OECD, 2017). Increased coverage, including across remote rural areas, also helps to integrate factor as well as goods and services markets. Governments have a direct and indirect role, through public investment in capital infrastructure and public/private partnerships, as well as policies to encourage private investment, such as the adoption of common protocols and standards for the digital infrastructure and competitive auctions for spectrum.

42. Policies to promote economic integration across countries also encourage technological diffusion. Trade, foreign direct investment, and global value chains are key means by which countries can learn from each other (Keller, 2004). The evidence suggests that globalization has contributed to the diffusion of technology—measured, for example, by the citation of international patents—which in turn has created positive productivity spillovers and fostered income convergence (IMF, 2018b). Moreover, technology diffusion is a two-way street where even the most innovative countries benefit from the innovation of others. This bodes well for the future, as countries such as South Korea and China are joining the group of economies that has typically originated the bulk of international patents. In order to fully reap the benefits of an integrated global market, an open trading system needs to be coupled with appropriate protection of intellectual property rights to incentivize international engagement by innovators (IMF, 2016b; and IMF, 2018b), for the same reasons that underpin the complementarity between product market deregulation and patent protection mentioned above.

43. Ensuring that markets are ready for change and that social safety nets are in place will facilitate the reallocation of capital and labor. A comprehensive effort in this direction is key to maximize the benefits from technological progress. In particular, complementing the product market reforms discussed before, labor market reforms should aim at protecting workers rather than jobs, which means that policies to reduce labor market duality and informality—including less stringent employment protection and lower labor tax wedges—must be accompanied with effective social safety nets. Existing regulations should not stand in the way when new technologies change existing occupations, for example in the area of professional services, provided that quality and consumer protection standards are maintained.

44. Country needs differ. As with structural reforms in general (IMF, 2016a), priorities differ based on the existing structural reform gaps and other country-specific circumstances. For example, the scope for product market deregulation is even greater in most emerging G-20 countries than it is in their advanced G-20 counterparts. Likewise, labor market reforms that reduce employment protection tend to be more effective when undertaken in an expanding economy (see also the discussion in Section 3.C).

B. Policies to Support Adjustment and Reduce Inequality

45. New technologies are hastening the shift from labor- to capital-intensive production, with an impact on labor markets and income distribution. These developments have been found to drive down demand and reduce relative wages for routine-task-based occupations. At the same time, they tend to create additional demand for high-skill, high-wage occupations complementary to new technologies, as well as for occupations that are difficult to automate such as low-skill, low-wage service sector jobs (Aghion, Jones, and Jones, 2017; Acemoglu and Restrepo, 2016; Autor, 2015). This has created concerns about job and income polarization, rising income inequality, and the possibility that capital-intensive technologies may eventually reduce aggregate demand for labor (Acemoglu and Restrepo 2017a and 2017b).

46. Policies should primarily focus on smoothing transitions and reducing skill-mismatches in labor markets, while the tax/benefit system can be used to ensure that gains are broadly shared. These involve three general areas: (i) direct short-term support through social safety nets and selected Active Labor Market Policies (ALMPs) to help displaced workers through transition periods (IMF, 2014 and 2016a); (ii) where needed and desired, the tax/benefit system has an important role to play in redistributing income after market outcomes; and (iii) adjustments to the education and health systems to raise the quality and quantity of the human capital of new labor market entrants, prepare workers for lifelong learning and adaptability to technological change and ensure long-term skill matching.

47. A comprehensive approach promises important synergies. Protecting workers by ensuring social safety nets will help them to better cope with the changes ahead, while making their reallocation to where they are most productive more likely—especially, if product market reforms in the product market allow new firms to enter and innovate. At the same time, well-targeted investment in human capital can not only make growth more inclusive, it also promises to facilitate innovation and technological progress by lifting the aggregate skillset of the workforce to match the needs of the new technologies.

Transitional Support and Direct Redistribution of Gains

48. Transitional support for displaced workers will help smooth the adjustment. In the short term, direct support for workers can be provided through selected ALMPs. These can either include direct support for displaced individuals—such as job search assistance, retraining, and geographical mobility support—or employment incentives—such as hiring and wage subsidies. The effectiveness of these schemes has varied among countries, suggesting that it depends on the particular economic circumstances, the nature of the program, and the targeted groups (see Box 2 for a description of ALMPs and country experiences). Given the increasing role of the gig economy in labor markets, training and benefits linked to individuals rather than jobs will be particularly important. These support policies can complement policies facilitating reallocation of jobs; for example, less stringent employment protection laws for regular workers.

49. In line with country circumstances, fiscal instruments can help ensure that expected gains from technological advances are widely shared. Through direct taxes and transfers, fiscal policy can influence the post-market income distribution in the short and long term. These policies, though, need to be carefully designed to minimize efficiency costs—such as disincentives to work, save, or invest—and to ensure desired distributional outcomes. Though achieving this careful calibration may be difficult, these policies can be powerful. For example, raising a broad-based indirect tax (such as a Value Added Tax (VAT) while ensuring that the impact on the most vulnerable is being cushioned) to finance an income tax cut that benefits primarily the middle class can distribute the gains from technological change much more evenly (IMF, 2018a).[13]

Investing in Human Capital

50. New technologies can increase skill-mismatches between workers and jobs. Technological change is expected to render individuals' skills redundant at a more rapid rate than in the past. High and persistent mismatches between skills offered by workers and demanded by employers create labor market rigidities, constrain the growth of innovative firms, and may increase wage inequality as firms depress wages owing to poorly-matched skills (OECD, 2015a). This is costly at the macroeconomic level, increasing structural unemployment and reducing growth through human capital loss and productivity-related skill bottlenecks (European Commission, 2013).

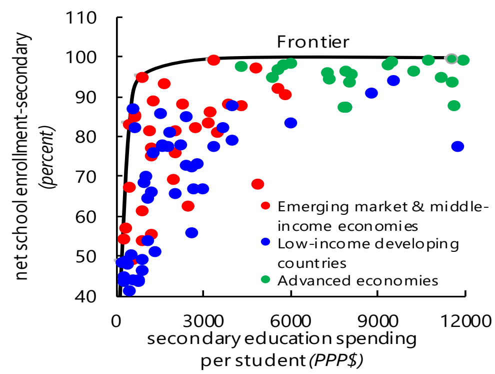
51. Policies should address skill-mismatches through improved education and continuing training. Ensuring universal and high quality basic and secondary education is critical to help individuals adapt to new technologies (Autor, 2013), and expanding tertiary education will open the door to jobs supporting the development of these technologies in the first place. From early learning to secondary education, the right balance has to be found between endowing students with the necessary tools in science, technology, engineering, and mathematics (STEM) on the one hand, and a general curriculum that emphasizes critical thinking, decision-making, problem-solving skills and empathy on the other. At the tertiary level, this may mean expanding liberal arts education. While

[13] This change in the tax regime could be particularly effective in advanced economies experiencing income and consumption polarization.

there is evidence pointing to the importance of building skills early (Heckman and Carneiro, 2003), this should be coupled with enhanced access to continuing (adult) education to ease the tension between longer working lives and the faster depreciation of human capital brought about by the expected acceleration of technological progress.

52. There are potential efficiency gains in education. While existing educational standards and goals differ across countries, the rather wide dispersion in education costs among and within advanced and emerging economies, especially for tertiary education, points to the need to assess the effectiveness of education spending.[14] Moreover, evidence on net school enrollment and education costs over a large sample of advanced, emerging and low-income countries suggests that some improvement in education outcomes could be achieved even within existing budget envelopes (IMF, 2018c; Figure 6).

Figure 6. Government spending on education and outcome 1/



Sources: Garcia-Escribano and Liu 2017; and IMF, *Fiscal Affairs Department Expenditure Assessment Tool.*
1/ Data from latest year available.

General Equilibrium Considerations: Income Redistribution, Fiscal Costs and Distortions

53. Human capital investment can improve the distributional impact of technological change, but it comes with an upfront fiscal and economic cost. Policies can accommodate the structural adjustments brought about by technological advances—including through selected ALMPs and higher human capital investment. As argued above, many countries could improve education outcomes under constant budgets through efficiency gains. However, because there are limits to such gains, upgrading human capital investment policies is likely to entail fiscal costs and can thus introduce distortions. For example, financing it through an income tax, while raising revenue—and potentially also impacting redistribution—will have a detrimental effect on labor supply and reduce growth. Overall, the upfront fiscal costs of education policies need to be weighed against the longer-term gains from enhanced human capital, output, and tax revenues.

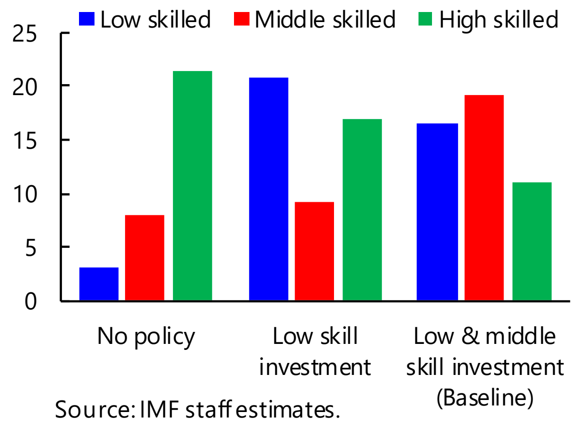
54. Simulations can illustrate some of these tradeoffs (see Box 2 for details). The starting point is an assumed 10 percent increase in the elasticity of substitution between capital and labor, which is used as a proxy for the impact of new technologies such as automation on factor intensity. These results are computed using a heterogeneous-agent general equilibrium model calibrated for the U.S. economy, which tracks workers' income by skill levels. To simplify, the model focuses on the income levels of three broad skill groups—low, middle, and high.

[14] For a discussion of dispersion in the cost of tertiary education in OECD countries, see OECD (2017).

55. The assumed advance in technology increases productivity and GDP, but it also raises inequality. The increase in income of the high-skilled is higher than that of lower-skill workers. As a consequence, while all skill groups participate in the assumed technology-driven surge in aggregate income, the relatively large increase in high-skill workers points to an increase in inequality (Figure 7 – No Policy).

Figure 7. Scenario analysis: Income effect of human capital investment without tax increase

(income after taxes and transfers; percent change)



Source: IMF staff estimates.

56. Human capital investment is a powerful tool to redistribute gains from technology. To illustrate the direct effect of skill building, two scenarios are simulated. The first scenario assumes a targeted increase in the human capital of low-skill workers, while the second model assumes an increase for both low- and middle-skill workers. The underlying cost estimates match average education cost conditional on workers' starting skill level in advanced OECD countries.[15] The initial assumption—to be lifted below—is that the government can finance the additional human capital investment without raising taxes by cutting unproductive spending elsewhere.[16] Key findings are:

- *Educating low-skilled workers reduces inequality but might intensify income polarization.* In this illustrative scenario, the government invests about 2 percent of GDP to reduce the share of low-skilled workers in the labor force by 4 percentage points overall, with half of these workers becoming middle-skilled and the other half accumulating enough human capital to become high-skilled. Compared to the no policy scenario, this reduces inequality by increasing income growth of low-skill workers relative to other types (Figure 7 – Low Skill). This is due to the relative scarcity of low-skill workers and the increased demand for services provided by the remaining low-skill workers, which rises as all incomes rise.[17] Note, however, that while this policy reduces inequality, it also generates significant income polarization, as the relative supply of medium-skill workers (vis-à-vis low-skilled ones) increases while the relative demand for them declines.

- *Educating low- and middle-skill workers reduces polarization, but is costlier.* In this other illustrative scenario, the government follows a broader human capital investment strategy such that the shares of low-skill and middle-skill workers drop by 2 percentage points of the labor force each, with all newly educated workers graduating to the highest skill level. The overall fiscal cost is somewhat higher, at about 2.5 percent of GDP (Figure 7 – Low & Middle Skill). This strategy

[15] The model makes the simplifying assumption that the additional cost of education is the same regardless of the stage of workers' careers. The cost of educating adults could be different from that of educating young people.

[16] As calibrated, the model would suggest that human capital investment reaps positive GDP effects *independently* of its financing—which may not hold always or for every country. However, in what follows the discussion focuses exclusively on the relative income and GDP effects of different forms of financing.

[17] Note that the formerly low-skill workers who have become middle or high skill see a direct rise in their wages.

eventually yields income gains for the middle skilled that are broadly similar to those of low-skill workers, and both enjoy larger (percentage) increases than high-skill workers.

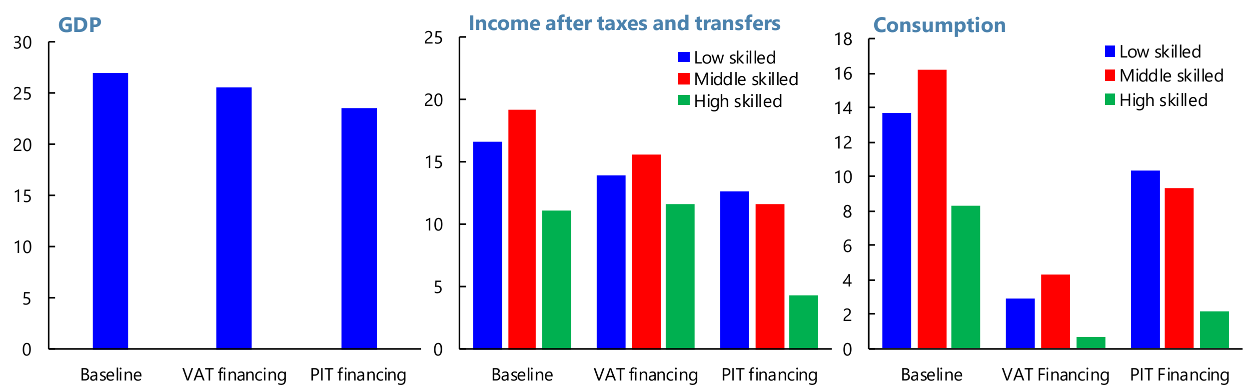
57. However, if additional education spending is financed through taxes, GDP growth will be lower than in the baseline and the distributional picture becomes more complicated. One important aspect is that higher taxes will come at the cost of distortions and efficiency losses (relative to a scenario where education is financed only by a cut in unproductive public spending), which reduce the income available to be shared by all skill groups. The other is that, as discussed earlier, the tax increase will have a distributional effect of its own, which comes on top of the distributional impact of the human capital investment it is financing.

58. Simulations illustrate the impact of two alternative tax financing strategies. The exercise focuses on the second, broader human capital investment scenario described above, which includes up-skilling both low- and middle-skill workers. It considers two alternative financing assumptions: a value-added tax (VAT) and a progressive income tax (PIT).[18] The key takeaways can be summarized as follows:

- *Tax financing creates distortions compared to financing through cuts in unproductive spending*. While higher human capital investment per se will raise GDP growth, the need to finance the additional spending through higher taxes will curb growth (left chart, Figure 8). This suggests that policymakers should take into account the full budgetary consequences of a human capital investment strategy.
- *VAT financing limits the distortionary impact, although at the cost of higher inequality compared to progressive PIT financing*. Education financing under the VAT is more efficient than under a PIT—aggregate GDP growth will be relatively higher—but it is also regressive (middle and right charts, Figure 8). Under VAT financing, high-skill workers are no worse off than under the no-tax scenario, while low and medium-skill workers bear most of the cost, blunting the positive income effects from the increase in their human capital. Under progressive PIT financing, the high-skill workers

Figure 8. Scenario analysis: Impact of human capital investment financed by higher taxes

(percent change)



Source: IMF staff estimates.

[18] The new technologies, though, may also place challenges for increasing taxation. See Section 3.C.

bear most of the cost of education policies, but labor supply is distorted from higher taxes on the most productive individuals.[19]

59. These results confirm the advantages of a comprehensive approach to supporting adjustment and reducing inequality. While human-capital centered strategies have many advantages—not least because they tackle some of the root causes of the asymmetry in the way technological advances are expected to impact workers at different skill levels (IMF, 2018a)—adjustments to the tax/benefit system also have an important role to play. Where taxes need to rise to finance higher spending on education, policymakers should not only consider their impact on growth and the fiscal bottom line, but also the implied change in the distribution of income.

C. A Look at National and International Policy Frameworks

60. Given the possible magnitude of the technological changes ahead, a more fundamental adjustment of policy frameworks may be required. The potential challenges associated with structural reallocation, a faster depreciation of human capital, and changes in the length and nature of worker-firm relationships come against the backdrop of preexisting trends such as aging and the lengthening of working lives. This suggests that, in addition to the policies discussed in Sections 3.A and 3.B, there might be a need for a closer look at whether public policy frameworks around social safety nets, education, the tax-benefit system, and competition are up to the expected challenges, while taking into account the budget implications of potential reforms. The answer will depend on country circumstances and, in some instances, will have to be guided by social preferences to weigh efficiency considerations and distributional concerns.

Social Insurance

61. A key challenge for social insurance and health systems is maintaining coverage in the context of more fragmented work lives and cross-border mobility. The eligibility for social insurance—which includes pension and unemployment benefits—is usually conditioned on accumulated contribution records. This implies that increasingly fragmented work histories and affiliation to schemes governed by different eligibility and benefit rules can limit the ability of individuals to obtain coverage. This is particularly relevant for pensions systems involving permanent benefits backed by a long employment record—and many health care systems face similar problems—while unemployment benefits are usually temporary and based on quasi-contemporaneous eligibility criteria. There is a case for moving early on such reforms, given the transitional issues involved—in systematic pension reforms, for example.

[19] Simulations assuming financing through a corporate income tax (CIT) have been performed as well. They suggest that a CIT would involve a larger tax burden on the high-skill workers—who have the highest income and thus own the largest share of capital—as with the progressive PIT. In such a scenario, the CIT would have more distortionary outcomes than the PIT.

62. Portability of benefits and adjusting accrual rules are of particular importance. Several policy options should be considered:

- *Domestic portability of social insurance*. The regulation of pension schemes—in particular occupational schemes—should allow transfers of assets and liabilities or, in the case of unfunded schemes, recognition of accrued rights. Steps to ensure the portability of accrued unemployment insurance benefits would also be important.
- *Health systems.* Safeguarding coverage also requires portability of these benefits, which will require public involvement, independently of the provision system or the status and sector of employment.
- *Contributions.* Pension scheme rules need to move towards assessing benefits based on complete work histories to better respond to career fragmentation.
- *Redistribution*. Social insurance systems should generally aim at ensuring protection and flexibility, while redistribution issues should be primarily tackled by taxation and social benefits and assistance.

Social Assistance

63. Increasing demand on government-provided income support will put social assistance systems to the test. While societal preferences and fiscal constraints differ across countries, achieving broad coverage of those affected by technological advances will help avoid unwanted distributional outcomes and mitigate risks by building consensus for reforms to unleash the potential gains from technological change.

64. Among the most important policy options are:

- *Secure coverage while ensuring efficiency*. This will mean closing coverage gaps while reducing take-up errors and revising program design to curb disincentive effects—such as those associated to high implicit taxes on labor market participation.
- *Leverage technology*. At the same time, policies should make the best possible use of the advantages offered by technological advances for identification of beneficiaries, monitoring eligibility criteria, and enhancing administrative processes and delivery mechanisms (IMF, 2018c).

Taxation

65. Given the likely pressures on the public finances from education spending and other measures, the impact of technological change on revenue deserves close attention. In principle, the higher income growth from technological advances could lift revenues and contribute to the financing of higher spending. The profits often associated with new technologies are not necessarily "pure rents", as the cost of innovation and other fixed costs need to be covered. But to the extent that such rents exist, they present an attractive tax base for governments seeking to finance new spending and redistribute income. Another reason to pay attention to profits associated with new technologies is the existing asymmetry in corporate tax revenue across comparable firms in different sectors.

66. At the same time, the new technologies create challenges to effectively collect revenue from corporations. Highly digitalized firms typically hold a high share of intangible assets—for example, datasets, algorithms, patents, or trademarks. Such assets are not only highly mobile across borders, but also hard to value, making them prone to major international tax avoidance trough profit shifting to lower-tax jurisdictions. Indeed, the tax burdens on intangibles-intensive corporations tend to be systematically lower than for traditional brick-and-mortar companies. The growing importance of digitalization thus undermines the revenue potential of taxing the growing share of returns to capital. Tax competition complicates matters further: as multinational tax bases are mobile across borders, countries compete for them by lowering tax rates and eroding their corporate tax revenues.

67. New technologies also create incentives to shift to harder-to-tax self-employment. As argued in Section 2, the technology behind digital platforms has changed the nature of the relationship between workers and employers, from traditional long-term permanent employment to short-term temporary task-based contracts executed by self-employed individuals. This poses a risk to government tax revenues, as unincorporated businesses are typically harder to tax in practice and tend to generate smaller amounts of income often falling below tax thresholds.[20] This could also reduce social security contributions and induce adverse selection whereby low-risk/high-skilled workers exploit opportunities to opt out of mandatory employment insurance, while the high-risk/low-skilled are excluded from insurance against risks such as disability or unemployment.

68. However, governments can use digital technologies to improve tax collection (IMF, 2018c). Technology may allow governments to make tax administration more efficient, for example, through cooperation with digital platforms to access data that can alleviate information constraints, strengthen enforcement, and allow better quantification of misreported or undocumented activity. Platforms can also act as custodians for the tax administration by withholding tax on behalf of sellers, something that is already taking place for single-stage indirect taxes in some countries (e.g., Airbnb). Digital technologies can also help governments to foster the taxation of wealth, which has historically been difficult to collect due to information constraints, especially with respect to offshore wealth holdings. Finally, new technologies can also improve social benefit delivery; for example, public expenditure for poverty reduction can be better targeted by using biometric technology (Gupta and others, 2018).

Aspects of International Cooperation

69. International cooperation will be critical in some areas, notably on tax and social insurance issues:

- *Tax cooperation*. This will avoid unwanted tax competition in a context in which, as noted above, tax bases are highly mobile amid profit-shifting by multinational companies and highly digitalized companies for which intangible assets play a fundamental role in conducting their operations (OECD, 2015). Using the new digital technologies, internationally-coordinated efforts

[20] For measures and country experiences on the financing of social protection system, see International Labour Organization (2018).

can also improve tax transparency and exchange of taxpayer information, which could enable governments to reinvigorate the use of wealth taxes.

- *International portability of pensions.* Another difficult challenge that will require international cooperation is ensuring the international portability of pension entitlements. Bilateral social security agreements between countries that regulate how service times are recognized among different systems need to be systematically expanded and standardized to allow the payment of multiple, additive benefits from different defined benefit schemes.

70. Given the new questions raised by technological change for competition policy, a case can be made for cross-country coordination with regard to multinational corporations. One issue is the ability to closely monitor pricing behavior and take action against predatory practices. Given that many of these issues occur simultaneously across countries, there is a case for sharing the experience gathered and best practices internationally. Another issue is the evaluation of mergers and acquisitions. Where economies of scale are realized at the global level—such as in the digital domain—but consumers may be affected differently across geographical areas, the evaluation of these operations would benefit from enhanced cooperation between competition authorities. Likewise, greater coordination could also help better address cases where mergers increase market power in export markets but not domestically, or in some parts of the supply chain but not others—leading to potentially different approaches and decisions by the different national authorities involved.

COUNTRY NEEDS AND TIMING OF POLICIES

71. The priority assigned to the various recommendations and their best sequencing vary across policy goals. In principle, while all countries should take immediate steps to *facilitate technological advances* and *close data gaps*, the timing of policies to help with the *adjustment* will depend on the speed with which technological advances reshape production processes in general, and labor markets in particular. This speed may differ between advanced and emerging economies. The updating of *policy frameworks* is a longer-term challenge that should be based on careful analysis and a clear understanding of each country's societal preferences.

72. As discussed in Section 3, the best-designed structural reforms to facilitate growth take into account the economic environment in which they are to be implemented (IMF, 2016c). Indeed, the IMF's guiding framework for structural reforms suggests taking into account (*i*) countries' respective level of economic and financial development. For example, many advanced economies might find innovation-enhancing or labor market reforms critical, while some emerging markets might prioritize improving governance or the functioning of product markets. Another guidepost is (*ii*) the position in the economic cycle, as some reforms are more powerful under already strong demand conditions. This holds, for instance, for reforms of job protection for regular contracts (IMF, 2016a). Finally, (*iii*) the available macroeconomic—particularly fiscal—policy space matters. In particular, where budget constraints are binding, lower- or no-cost measures with positive demand effects of their own (such the lowering of entry barriers in services or good markets) might be relatively more attractive than reforms that require fiscal space to offset any short-term costs.

73. While all countries have room to enhance government efficiency, the specifics will depend on the existing framework (IMF, 2018c). For example, where existing institutional frameworks remain lacking, new digital technologies can play a particularly important role in delivering income and other support to the intended beneficiaries (see Section 3). The existing institutional setting also matters for the type of adjustment to social insurance frameworks policymakers will want to consider. For instance, defined-benefit pension systems will generally face greater challenges adapting to increasing cross-country mobility than contribution-based ones—for which portability is less of an issue.

Table 1: Future of Work—Summary of Recommendations	
Improve productivity measurement	• **Improving quality and composition adjustments in price indices for ICT goods and services and GDP.** Quality adjustment techniques and updating assumptions and parameter estimates used in existing procedures can improve the compilation methods of price indexes. New digital products must be added in a timelier manner to the price index baskets to avoid inadequate and delayed adjustments. Special procedures for updating samples and products should be introduced to ensure survey data used to compile GDP includes new digital businesses and products. Statistical agencies should have access to tax and other administrative data subject to confidentiality safeguards. • **Accounting for the growing use of outsourced services in production.** New productivity statistics that focus on value added rather than gross output and include labor from outsourcing contractors, temporary help agencies, and the gig economy. • **International collaboration to address measurement issues associated with the operations of MNEs.** Developing new measures of global production of MNEs; e.g., to capture the distortions due to relocation of intellectual property assets.
Improve measurement of labor markets	• **Collecting data on the number, income and other characteristics of gig economy workers.** Collecting data on individuals selling products and services in digital marketplaces and on contingent work, which could be done by refining employment surveys and improving estimates of participants and earnings through the incorporation of data from new sources like digital payment processors or tax databases. • **Developing indices to measure the impact of technology and artificial intelligence.** New indicators on skill utilizations, labor market skill mismatches, career path prospects and effectiveness of retraining programs to help inform future retraining and education policies. This could be done by using information through data mining and artificial intelligence techniques from non-standard sources and integrating with statistics from household and employer surveys.
Facilitate technological advancement	• **Product market reforms:** Reforms to improve competition through reduced barriers to entry/exit and costs of starting a business, and improvements in the overall business climate—tailored to country circumstances. • **Labor markets reforms:** Reforms should aim at protecting workers rather than jobs, including measures to reduce labor market duality such as less stringent employment protection and lower labor tax wedges. These should be accompanied by expanded social safety nets. Country-specific circumstances should guide implementation. • **Patent protections:** Depending on the existing market structure in industries, time-limited rights to monopoly profits to spur innovation can be used. In these cases, robust patent regimes should be supported. • **Access to finance:** Improved access to finance—particularly through fintech—can improve access and competition, but must be accompanied by strengthening of regulatory oversight and improved cyber security.

Table 1: Future of Work—Summary of Recommendations	
	• **Digital infrastructure:** Investment through public, private, or public-private-partnerships, to support technological adoption and diffusion. Coordination on the adoption of common protocols and standards for digital infrastructure and competitive auctions for spectrums. • **Internationally integrated open markets:** Openness to foreign direct investment, trade, and global value chains to facilitate technological diffusion. Openness should be accompanied by appropriate protection of intellectual property rights.
Support labor market adjustments and reduce inequality	• **Active labor market policies to support labor market transition:** Direct support, linked to workers and not jobs, can be provided through carefully designed ALMPs calibrated to country-circumstances, including: (i) job search assistance; (ii) retraining; (iii) income support; and (iv) private sector hiring and wage subsidies. • **Fiscal policy:** Direct taxes and transfers to help ensuring that gains from technological change are equally shared. • **Human Capital Building:** Long-term education policies to ensure universal and high quality basic and secondary education equipping individuals with critical thinking, problem-solving skills, social and emotional skills and the ability to adapt to change. It should be focused on addressing skill-mismatch in the labor force.
Updating policy frameworks	• **Social insurance**: Bilateral social security agreements need to be systematically expanded and standardized. Regulation of pension schemes should allow transfer of assets and liabilities, and recognition of accrued rights. Portability of accrued unemployment insurance benefits should be ensured. • **Social safety net**: ensuring broad coverage will be important. Programs should be (re)designed to reduce take-up error, curb disincentive effects, and close coverage gaps. Technology should be used to improve administration, monitoring, and delivery. • **Tax reform**: digital technologies should be used to make tax administration more efficient, to act as a withholding tax custodian, and to foster the taxation of wealth. International cooperation to improve tax transparency, exchange taxpayer information, limit international tax competition, and reform social security systems will be useful. • **Competition policy:** coordination will help address market power concerns that spillover across countries through digital domains and for multinational companies.

Box 1. The Gig Economy

The gig economy includes both physical and digital services, primarily provided by independent workers in an on-demand or short-term basis. There is considerable uncertainty about its size, but there are indications that the number of participants is large and that official statistics may be underestimating its magnitude in income terms.

Gig economy platforms allow independent workers to supply on-demand and short-term services.[1] Platforms—such as Uber and Upwork—are responsible for collecting payments and passing them on to the worker supplying the services—often even setting the price. Independent work in the gig economy represents a labor service, and in many cases, the ostensibly independent workers could be conceived of as employed by the platform. Indeed, regulation of gig economy platforms as employers and collective bargaining by the workers are part of the public policy debate (Artecona and Chau, 2017; and Johnston and Land-Kazlauskas, 2018).

The gig economy comprises both physical services that workers provide directly to the client and services delivered digitally over outsourcing platforms. The physical services have been termed "on-demand" services—they are the peer-to-peer labor portion of the sharing economy. As for outsourcing, the platforms of the digitally-delivered segment of the gig economy facilitate crowdsourcing (the less skilled types of tasks) and freelancing activities (the more skilled types).[2] Overall, where ridesharing platforms—such as Uber—are legal, on-demand services comprise a larger share of the gig economy than outsourced tasks.

Tax data suggests that official statistics may underestimate gig economy employment and earnings. Surveys of households' labor market activity typically lack specific questions about work in the gig economy—or even about contingent (on-call) work in general (Mitchell and Brynjolffson, 2017)—and respondents to employment surveys tend to underreport their platform-based work unless specifically asked about it.[3]

Aggregate estimates of employment and labor income derived from household surveys could potentially miss significant amounts of gig economy work. In fact, a comparison of non-employee workers in the U.S. Current Population Survey with the number of individuals receiving non-employee income in tax records points to underreporting (Abraham and others, 2017).[4]

Estimates based on private data suggest that, in terms of incomes, the size of the gig economy is still small. Vaughn and Daviero (2016) estimated that transactions for peer-to-peer transport in the 28 countries of the European Union in 2015 amount to just over Euro 5 billion, while other kinds of gig economy services amount to less than Euro 3 billion—which implies that together these represent 0.06 percent of gross value added. Reports by *Staffing Industry Analysts* offer U.S. and global estimates. For the United States, spending on "human cloud services"—the term used for the gig economy—is estimated at USD 11.5 billion in 2015 (0.06 percent of GDP). As for the global size of human cloud services, a 2017 report points to a lower bound estimate of USD 47 billion in 2016—of which USD 40 billion come from ridesharing. These reports also suggest that work in the gig economy is frequently a secondary source of income—this is the case for almost 70 percent of the U.S. participants.

However, the size is larger if gauged by number of participants. A report by Pew Research suggests that 8 percent of the adult population in the United States participates at least once a year in the gig economy. Similarly, the U.S. Bureau of Labor Statistics estimates that about 10 percent of the U.S. labor force was employed in alternative work arrangements in 2017, which encompasses the gig economy but is not necessarily a precise measure of it. Their data also suggests that this share has been broadly stable over the last decades. Other estimates point to a lower number. Based on an analysis of U.S. bank account activity, Farrell and Grieg (2017) suggest that people receiving income from online labor platform work during June 2016 represented 0.5 percent of the adult population—or 0.7 percent of the labor force. In the United Kingdom, an online survey found that 4 percent of respondents had worked in the gig economy at least once per month in 2015 (Huws and Joyce, 2016). The outsourcing platform component of the gig economy is relatively large in the Philippines, where active workers may have exceeded 2.2 percent of the workforce in 2015 (Heeks, 2017).

____

[1] Some ascribe a broader meaning, using the term for all short-term work regardless of how it is arranged.

[2] Items commonly supplied on outsourcing platforms include software, translations, and information.

[3] The gig economy includes work facilitated by a digital platform, while contingent work encompasses a broader category of work that can be arranged without digital technologies.

[4] The survey data imply no growth in independent work following the emergence of the gig economy, while the tax data imply a substantial increase. Misreporting of independent work as ordinary employment plays a small role in this discrepancy, but independent work that is not reported at all accounts for most of it.

Box 2. Country Experience with Active Labor Market Policies

Active labor market policies (ALMPs) of various sizes and scope have been employed across G-20 countries. They have had varying degrees of success depending on their design and country circumstances. This box provides of brief overview of ALMPs and presents some country experiences.

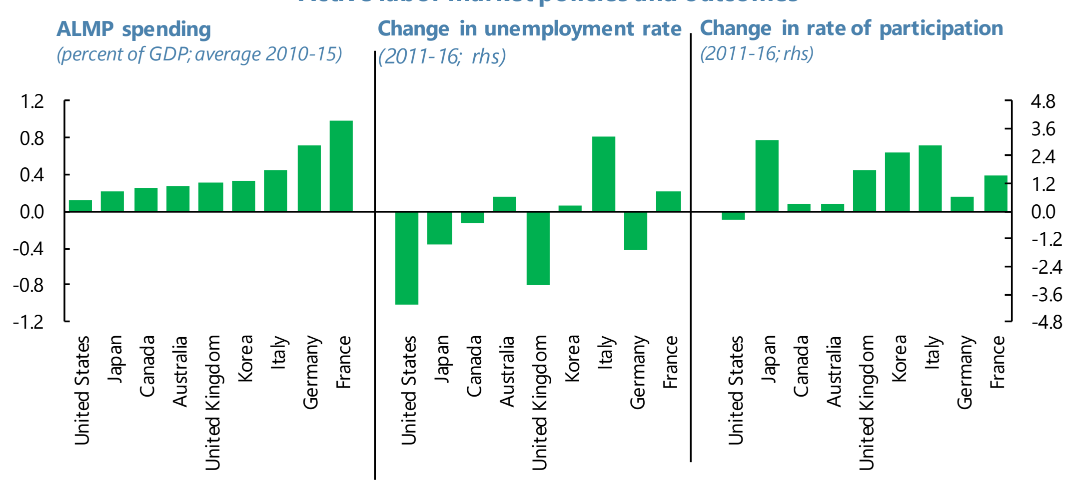
ALMPs in various forms can reduce labor market frictions and help reallocation.

- *Job-search assistance* including counseling and placement assistance can be effective in raising short-term employment prospects and reducing unemployment (Meyer, 1995; and Card, Kluve, and Weber, 2015).
- *Retraining* to equip displaced workers with new skills has widespread use (Card, Kluve, and Weber, 2015).
- *Private sector hiring and wage subsidies* can encourage firms to generate new jobs and improve the desirability of employment (IMF, 2012).
- *Well-targeted public-sector job creation schemes* may increase labor market attachment and maintain human capital, although skills may not be transferable to the private sector and the impact on structural unemployment has often been limited or even counterproductive (Card and others 2009).

The size, scope, and focus of ALMPs vary significantly across G-20 countries. Effective ALMPs must be adaptable and tailored to country circumstances. Indeed, evidence shows there is significant variation in their use across countries—in 2015, public expenditure on ALMPs ranged from 0.01 to 1.01 percent of GDP across G-20 advanced economies.[1] In most countries, expenditure on ALMPs exceeded that of passive labor market policies, although spending has declined since 2010 in two-thirds of the countries. Public employment services and administration (e.g. job search assistance and income support) were the most common, followed by retraining.

The effectiveness of ALMPs depends on the nature of the program, targeted groups, and the coordination with other policies. ALMPs generally support employment, and tend to be more effective when implemented in concert with complementary macroeconomic policies.[2] Aggregate ALMPs spending shows a strong correlation with labor force participation, though tells us little about the effects on unemployment, which are *a priori* ambiguous (see figure). Evidence on specific policies is more telling: job-search assistance may reduce the duration of unemployment claims by up to 4 weeks (Meyer, 1995), retraining may increase employment probabilities by up to 15 percentage points (Card, Kluve, and Weber, 2015), and earned income tax credits can raise employment rates for single mothers by 3 percentage points (Eissa and Liebman, 1996).

Active labor market policies and outcomes



Sources: Haver Analytics; OECD; and IMF staff calculations.

Lessons on the design of labor market policies may be drawn from individual experiences:

Denmark. In 2015, public spending on ALMPs reached about 2 percent of GDP, the largest among OECD countries. About two-thirds of spending was focused on training and supporting employment. ALMPs are part of the Danish "flexicurity" model, which balances relatively low employment protection legislation— flexible rules for hiring and firing—with relatively high levels of unemployment insurance and ALMPs to support job search and reduce the duration of unemployment spells. Under the flexicurity model, Denmark has had relatively low long-term unemployment rates and high levels of perceived job security.

Germany. Since 2005, Germany has experienced a decline in its unemployment rate, and a steady increase in labor force participation, particularly for older workers and women. These trends have coincided with a comprehensive set of reforms to increase employment that were implemented in 2003-05, which included a restructuring of the Federal Labor Agency and revamped ALMPs to improve job search assistance. More recently, access to continuing vocational education and training has improved for low-skilled long-term unemployed and older workers, introduced new mentoring programs for the youth, and expanded programs for asylum-seekers and refugees.[3]

South Korea. Spending on ALMPs averaged 0.4 percent of GDP from 2008-15. Unlike many other OECD countries, a bulk of these funds were spent on direct job creation, reflecting a traditionally large share of manufacturing in the economy. More recently, ALMPs have focused on the youth, who exhibit a higher rate of unemployment and inactivity than other groups. Recent youth initiatives have included vocational schools targeting industry-specific needs, job training and education in public institutions and large enterprises, financial support, youth hiring quotas in public entities, and subsidized internships for unemployed youth.[4]

---

[1] This includes Australia, Canada, France, Germany, Italy, Japan, South Korea, Mexico, and United States (OECD database).

[2] See IMF (2016a).

[3] See IMF (2017).

[4] See IMF (2018d).

Box 3. Modelling Education Policy Options

Model-based simulations illustrate how adverse distributional impacts of technological change can be mitigated by education policy.

Technological change. The model, based on Lizarazo Ruiz, Peralta-Alva, and Puy (2017), is a heterogeneous agent general equilibrium model calibrated to fit the U.S. as a benchmark economy. There are three types of agents in the model – low, medium, and high skilled—and two inputs into production—capital and labor. Capital is a substitute for middle- and low-skilled labor with an elasticity of 1.5, while capital and high-skilled labor are complements. The distribution of skills is exogenous and constant, but can be shifted by education policies. The impact of automation is simulated by a 10 percent increase in the elasticity of capital and labor substitution. The static framework abstracts from transition dynamics to focus only on the long term. Baseline simulations show a positive impact on aggregate income, but disproportionally benefiting the high-skilled. Policy scenarios are considered to improve redistribution.

Education Policies. In the model, within each skill level there is a range of education levels attainable which are reflected by the costs of education. Low skill workers have up to secondary education. Middle-skill workers' education ranges from post-secondary non-tertiary (the U.S. equivalent is a 2-year vocational college) to tertiary excluding research (the U.S. equivalent is a 4-year bachelor degree). High-skill workers' education is a range of tertiary including research (the U.S. equivalent is a 2-year Master's degree to a 5-year PhD). Policy scenarios focus on redistribution through education to improve human capital for low- and medium-skill workers. For simplicity and to better understand the underlying mechanisms at work, the model first assumes that these policies are financed by reducing unproductive government consumption:

- *Higher education spending on low-skill workers***.** In the first policy scenario, the model simulates an increase in the human capital of the low skilled such that the share of low-skilled in the labor force drops by 4 percentage points. Half of these workers become medium-skilled workers and the other half becomes high-skilled workers. Based on data on average education costs in the OECD, the cost of such a change ranges from 1 to 3 percent of GDP depending on where within the range of high-skill level the individuals attain (e.g. Masters versus PhD). The note uses a mid-point estimate of 2 percent of GDP.
- *Higher education spending on low- and middle-skill workers.* In the second policy scenario, the model is used to increase the human capital of both the low- and middle-skill workers to overcome income polarization realized by only educating the low-skill workers. The share of low- and medium-skill workers drops by 2 percentage points each, and all of these workers become high-skilled. Based on data on average education costs in the OECD the cost of such a change can range from 1.4 to 3.5 percent of GDP. We use a mid-point estimate of 2.5 percent of GDP.

Both policies boost income gains from technological advances. When focused on only low skill workers, human capital improvements boost GDP gains from 16½ percent (impact of technological change alone) to 23 percent (impact of technological and policy changes). Broadening the human capital investment to middle skill workers results in GDP gains of 27 percent. Improving the human capital of low-skilled workers allows them to profit from technological progress. It also makes low-skilled workers scarcer and demand for their services higher, boosting their wages. Educating middle-skill workers allows them to reap similar benefits from technological change as low-skill workers, and avoids a hollowing out of the middle.

Financing higher education spending involves efficiency and equality tradeoffs. Two different funding scenarios for higher education spending are considered: a value added tax (VAT) applied at a flat rate across all consumption goods and a progressive income tax (PIT) for all income earners above the median income. The VAT, while efficient and reducing GDP gains by less than the PIT, is regressive and see less income gains to low and middle-skill agents relative to high-skill. The PIT is more redistributive to lower income earners, but comes at the cost of lower GDP gains.

While indicative of potential gains, the results must be interpreted with caution. This is because the model is relatively simple and simulations illustrate only two potential paths for redistribution in the face of technological change and their financing options.

References

Abraham, K., Haltiwanger, J., Sandusky, K., and Spletzer, J., 2017, "Measuring the gig economy: Current knowledge and open issues." In Measuring and Accounting for Innovation in the 21st Century, ed. by Corrado, C., Miranda, J., Haskel, J., and Siche, D. (NBER).

Abdiraham, M., Coyle, D., Heys, R., and Stewart, W., 2017, "A Comparison of Approaches to Deflating Telecoms Services Output," IET/ONS working paper

Acemoglu, D. and Restrepo, P., 2016. "The race between machine and man: Implications of technology for growth, factor shares and employment," NBER Working Paper 22252.

Acemoglu, D., and Restrepo, P., 2017a. "The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment," NBER Working Paper No. 22252

Acemoglu, D. and Restrepo, P., 2017b. "Robots and jobs: Evidence from US labor markets," NBER Working Paper No. 23285.

Adler, G., Duval, R., Furceri, D. Celik, S.K., Koloskova, K., and Poplawski-Ribeiro, M., 2017, "Gone with the headwinds: Global productivity" IMF Staff Discussion Notes DSN/17/04.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P., 2005, "Competition and innovation: An inverted-U relationship," The Quarterly Journal of Economics, 120(2), pp.701-728.

Aghion, P., Akcigit, U. and Howitt, P., 2014, "What do we learn from Schumpeterian growth theory?" In Handbook of Economic Growth Vol. 2, pp. 515-563.

Aghion, P., Jones, B.F. and Jones, C.I., 2017," Artificial Intelligence and Economic Growth," NBER Working Paper No. 23928

Ahmad, N., Ribarsky, J., and Reinsdorf, M., 2017, "Can Potential Mismeasurement of the Digital Economy explain the Post-Crisis Slowdown in GDP and Productivity Growth?" OECD Statistics Working Papers, 2017/09.

Artecona, R. and Chau, T., 2017, "Labour issues in the digital economy," ECLAC Studies and Perspectives Series.

Autor, D. H., 2013, "The" task approach" to labor markets: an overview," NBER Working Paper No. 18711.

Autor, D. H., 2015. “Why Are There Still So Many Jobs? The History and Future of Workplace Automation,” Journal of Economic Perspectives, 29 (3): 3-30.

Autor, D. H., and Dorn, D., 2013. “The growth of low-skill service jobs and the polarization of the US labor market,” American Economic Review, 103(5), pp.1553-97.

Brynjolfsson, E., Rock, D. and Syverson, C., 2017, “Artificial intelligence and the modern productivity paradox: A clash of expectations and statistics,” NBER Working Paper No. 24001.

Byrne, D., and Corrado, C., 2017a, “ICT Asset Prices: Marshaling Evidence into New Measures,” Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2017-016.

Byrne, D., and Corrado, C., 2017b, “Accounting for Innovation in Consumer Digital Services,” Presented at the 5th IMF Statistical Forum.

Byrne, D., Fernald, J., and Reinsdorf, M., 2016, “Does the United States Have a Productivity Slowdown or a Measurement Problem?” Brookings Papers on Economic Activity (Spring): 109-157.

Card, D., Kluve, J. and Weber, A., 2010, “Active labour market policy evaluations: A meta-analysis,” The Economic Journal, 120(548).

Card, D., Kluve, J. and Weber, A., 2015, “What works? A meta analysis of recent active labor market program evaluations,” Journal of the European Economic Association.

Cavallo, A., 2017, “Are Online and Offline Prices Similar? Evidence from Large Multi-Channel Retailers,” American Economic Review 107: 283-203.

Chiacchio, F., Petropoulos, G., and Pichler, D. (2018), “The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach”, Bruegel Working Paper, Issue 2, April 2018.

Cheng, W., 2017, “Measuring the Digital Economy in China*,”* Presented at the 5th IMF Statistical Forum.

Clements, M.B.J., de Mooij, R.A., Gupta, M.S. and Keen, M.M., 2015, *Inequality and fiscal policy* (Washington: International Monetary Fund).

David, P.A., 1990, “The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox,” American Economic Review, Vol. 80, No.2.

Djumalieva, Jyldyz, Antonio Lima and Cath Sleeman, 2018, "Classifying Occupations according to their Skill Requirements in Job Advertisements," ESCoE Working Paper DP-2018-04.

Diez, F.J., Leigh, D., and Tambunlertchai,S., 2018, "Macroeconomic Implications of Market Power: International Evidence," IMF Working Paper, *Forthcoming.*

Duval, R. and Furceri, D., 2018, "The effects of labor and product market reforms: the role of macroeconomic conditions and policies," IMF Economic Review, 66(1), pp.31-69.

Eissa, N. and Liebman, J.B., 1996, "Labor supply response to the earned income tax credit," The Quarterly Journal of Economics, 111(2), pp.605-637.

European Commission, 2013, "The Skill Mismatch Challenge in Europe," In Commission Staff Working Document: Employment and Social Developments in Europe 2012.

Farrell, D., and Greig, F., 2017, "The Online Platform Economy – Has Growth Peaked?" JP Morgan Chase & Co. Institute.

Fort, T., 2017, "Technology and Production Fragmentation: Domestic versus Foreign Sourcing," Review of Economic Studies (2017) 84, 650–687.

Fougere, D., Kramarz, F. and Magnac, T., 2000, "Youth employment policies in France," European Economic Review, 44(4-6), pp.928-942.

Gal, P.N. and Hijzen, A., 2016, "The short-term impact of product market reforms: A cross-country firm-level analysis," IMF Working Paper No.116.

Guellec, D. and Paunov, C., 2017, "Digital Innovation and the Distribution of Income," NBER Working Paper No. 23987.

Gupta, S., Keen, M., Shah, A., and Verdier, G., 2018, "Digital Revolutions in Public Finance," Washington DC: International Monetary Fund.

Gutiérrez, G. and Philippon, T., 2017, "Declining Competition and Investment in the US," NBER Working Paper No. 23583.

Hawksworth, J., Berriman, R., and Goel, S., 2018, "Will Robots Really Steal our Jobs? An international analysis of the potential long-term impact of automation," PWC Report.

Heckman, J., and Carneiro, P., 2003, "Human Capital Policy," NBER Working Paper No. 9495.

Heeks, R., 2017, "Decent Work and the Digital Gig Economy: A Developing Country Perspective on Employment Impacts and Standards in Online Outsourcing, Crowdwork, etc.," Development Informatics Working Paper Series, No. 71.

Horton, J., Kerr, W.R., and Stanton, C., 2017, "Digital Labor Market and Global Trade Flows," NBER Working Paper No. 23398.

Huws, U., Joyce, S., 2016, "Size of the UK's 'gig economy' revealed for the first time," Crowd Working Survey, University of Hertfordshire, Hatfield and UNI Europa, Brussels, February. Available at: http://www.feps-europe.eu/en/publications/details/363

Johnston, H. and Land-Kazlauskas, C., 2018, "Organizing On-Demand: Representation, Voice, and Collective Bargaining in the Gig Economy," International Labour Organization Conditions of Work and Employment Series No. 94.

International Labour Organization, 2018, "Innovative Approaches for Ensuring Universal Social Protection for the Future of Work".

IMF, 2012, *Fiscal Policy and Employment in Advanced and Emerging Economies* (Washington).

________, 2014, *Fiscal Monitor, Chapter 2, October,* (Washington).

________, 2016a, *World Economic Outlook*, *Chapter 3*, April, (Washington).

________, 2016b, *Fiscal Monitor, Chapter 2,* April, (Washington).

________, 2016c, *Priorities for Structural Reforms in G-20 Countries.* IMF Staff Background Paper for the G-20 Surveillance Note. July. (Washington).

________, 2017a, *World Economic Outlook. Chapter 3,* April, (Washington).

________, 2017b, *Germany Article IV Selected Issues: Income Distribution and Labor Market Developments in Germany,* (Washington).

________, 2018a, *Technology and the Future of Work*. IMF Staff Note for the G-20, (Washington).

________, 2018b, *World Economic Outlook Chapter 4*, April. (Washington).

________, 2018c*, Fiscal Monitor, Chapter 2*, April, (Washington).

________, 2018d, *Republic of Korea Article IV Selected Issues: Labor Market Duality in Korea*, (Washington).

Katz, L.F., and Krueger, A.B., 2016, “The Rise and Nature of Alternative Work Arrangements in the United States,” 1995-2015. NBER Working Paper No. 22667.

Keller, W., 2004, “International technology diffusion,” Journal of Economic Literature, 42(3), pp.752-782.

Lizarazo Ruiz, S., Peralta-Alva, A. and Puy, D., 2017, “Macroeconomic and Distributional Effects of Personal Income Tax Reforms: A Heterogenous Agent Model Approach for the US,” IMF Working Paper No. 192.

Mandel, Michael. 2017, “How Ecommerce Creates Jobs and Reduces Income Inequality,” Progressive Policy Institute Policy Memo

Meyer, B.D., 1995. “Natural and quasi-experiments in economics. Journal of Business & Economic statistics,”13(2), pp.151-161.

Mitchell, Tom and Erik Brynjolffson, 2017, “Track how technology is transforming work,” Nature Vol. 544, Issue 7650.

Mokyr, Joel, Chris Vickers, and Nicolas L. Ziebarth, 2015, “The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?” Journal of Economic Perspectives 29(3): 31-50.

Nakamura, Leonard, Rachel Soloveichik and Jon Samuels, 2017, “Measuring the “Free” Digital Economy within the GDP and Productivity Accounts,” ESCoE Working Paper DP-2017-03.

National Academies of Sciences, 2017, “Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?” Washington, DC: The National Academies Press.

OECD, 2015a, *The Future of Productivity*, (Paris).

_______, 2015b, *Refining Regulation to Enable Major Innovations in Financial Markets*, (Paris).

_______, 2017, *Digital Economy Outlook*, (Paris).

Reinsdorf, M. and Quirós, G., 2018, “Measuring the Digital Economy,” IMF Policy Papers.

Scheiber, N., 2017, “Plugging into the Gig Economy, From Home With a Headset”, New York Times, November 12. https://www.nytimes.com/2017/11/11/business/economy/call-center-gig-workers.html.

Schneider, T., Hong, G. and Le, A., 2018, “Land of the Rising Robots”, Finance and Development Vol. 55 No.2, pp. 28-31.

Vaughan, R., and Daverio, R., 2016, “Assessing the size and presence of the collaborative economy in Europe,” PWC Report for the European Commission (DG GROW).

Ylä-Jarkko, M., Berry, F., and Stanger, M., 2018, “The Status of Price Statistics Compilation Practices in 196 Economies and the Relevance for Policy Analysis,” IMF Working Paper, *Forthcoming*.