EMPLOYMENT POLICY BRIEF

International Labour Office

NEW AUTOMATION TECHNOLOGIES AND JOB CREATION AND DESTRUCTION DYNAMICS[1]

Though the word "automation" dates from only the mid-20th century, earlier technological revolutions going back to the 18th century were characterized by automation and accompanied by fears of labour displacement. In these respects today's digitally-driven technological revolution is no different. This technological revolution is comprised of a diverse array of technologies blurring the lines between manufacturing and services and technological regimes more generally. Yet most archetypal of new automation technologies are computer-controlled robots, whose diffusion has been facilitated by rapidly expanding capabilities and falling costs. Mindful of the alarmist concerns accompanying the current wave of automation, the ILO Director General's report on the future of work asks "whether the unfurling technological revolution…is so far-reaching in its labour-replacing potential that it is inherently different from what has been experienced in the past, and on balance is an inhibitor rather than a generator of decent work.[2]

This policy brief addresses this question by providing the following:

- A critical review of recent empirical studies on the effects of new automation technologies on jobs, arguing for the importance of carefully distinguishing between the probability that a job *could be* automated and the probability that it *will be* automated, discussions of how the gap between these two is necessarily larger in developing countries, how nearly all these studies exclude the possibility of job creation dynamics by construction, and how translating the share of potentially automatable tasks and their associated working hours into the number of potentially automatable jobs depends on how not-readily automatable work is shared among workers.
- A discussion of multiple job creation and destruction dynamics and how these can offset each other at different levels of aggregation, ranging from specific tasks to the economy as a whole, providing illustrations from services and manufacturing.
- A discussion of the prospects for reshoring (a reversal of offshoring by multinational enterprises) resulting from new automation technologies negating the labour-cost advantages of developing countries in the production of such labour-intensive manufactures as apparel and electronics assembly, and the technological bottlenecks to such reshoring.
- A closing discussion addressing the possibility of a bias of perception resulting from the anthropomorphic characteristics of many new automation technologies and – even in the absence of overall job loss – the need for progressive policies to address the probable tendency towards growing inequality that would otherwise result from new automation technologies as well as the near certainty of a more rapid pace of job creation and destruction and the challenge for workers of transitioning from old to new jobs.

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Recent empirical studies

Several recent empirical studies address the effects of new automation technologies on jobs. Perhaps the most widely cited study estimates that 47 per cent of US jobs are at a high risk (greater than 70 per cent) of *potential* automation by computer-controlled equipment in the next 10 or 20 years.[3] This finding is based on estimates of differences in the risk of potential automation among occupations combined with the country-specific distribution of workers among these occupations. The risk of potential automation is based in turn on a database describing work characteristics of occupations combined with assessments made by machine-learning researchers of 70 occupations which are then imputed to 632 other occupations (based on similarity of work characteristics) for a total of 702 occupations.

The authors of this study note that their results refer to the probability that a job *could be* automated, whereas they are often misrepresented or misunderstood as the probability that a job *will be* automated. These are two fundamentally different things, for while the former is purely a technical consideration, that latter is also an economic consideration, depending on the relative costs of labour and automation technologies and ultimately on whether investing in new automation technologies is at least as profitable as existing alternatives. Since applying this method to different countries is entirely driven by differences in the distribution of workers among these occupations, the gap between the probability that a job *could be* automated and the probability that a job *will be* automated is systematically larger in countries with lower labour costs. In other words, equating *could be* with *will be* is particularly problematic for developing countries.

An ILO study applies this same method to five ASEAN countries – Cambodia, Indonesia, the Philippines, Thailand and Vietnam – and estimates that 56 per cent of jobs in these countries is at a high risk of displacement as a result of new automation technologies.[4] Though this is greater than the figure of 47 per cent for the US, the lower labour costs in these five ASEAN countries combined with other impediments to the implementation of new automation technologies suggests that the risk that jobs *will be* automated in these five countries in coming years is actually a good deal lower than in the US. A World Bank study applies this method to additional developing countries, and finds comparable figures of around 70 per cent or more for such countries as India, Bangladesh, China, Cambodia, Nepal and Ethiopia, though these are a good deal lower after an adjustment is made based on the slower pace of technology adoption in developing countries in the past.[5]

Yet there are important reasons to believe that even if the above estimates are represented as the probability that a job *could be* automated, they are nonetheless considerably overestimated. An OECD study applies an alternative method that more fully accounts for the variety of tasks within occupations as well how this differs across countries.[6] By doing so, the study estimates that only about nine per cent of jobs in the US are at a high risk (70 per cent, as in the prior studies) of potential automation, the same as for 21 OECD countries on average. It is worth noting, however, that there are tasks performed within the other 91 per cent of jobs not categorized as high risk that could be automated. The automation of these tasks could result in pressure for fewer working hours for any given worker or the consolidation of not-readily automatable tasks among fewer workers. For these reasons, the percentage of jobs at high risk of potential automation may well be higher than the figures provided by the study, partly depending on the number of hours a given worker spends on readily automatable versus not-readily automatable tasks.

This ambiguity is highlighted in a study by the McKinsey Global Institute to assess the automation potential of 2,000 work activities.[7] Based on their methods, for the US they estimate that 47 per cent of all work activities, equivalent to 46 per cent of total working hours, have the potential to be automated using existing technologies. They also provide global estimates based on data for 46 countries comprising 80 per cent of the global workforce, and estimate that just under 50 per cent of all work activities, equivalent to 51 per cent of total working hours, have the potential to be automated. At the same time, while fewer than five per cent of occupations are estimated have the potential to be *fully* automated globally, about 60 per cent of occupations have 30 per cent or more automatable work activities within them. Whether or not one takes these estimates at face value, translating the share of work activities or tasks and associated working hours that are potentially automatable into the share of *jobs* that are potentially automatable depends on how not-readily automatable work is shared among workers. This is not, of course, a narrow technological consideration, but ultimately depends on systems of industrial relations and broader social factors which vary widely among and within countries and which do not lend themselves to predictable, uncontested outcomes.

The OECD study goes on to emphasize that its methods and those of all the prior studies discussed can only account for job destruction dynamics and exclude job creation dynamics by construction. That is, it is *a priori* impossible for these methods to yield any positive effects of technology on employment. Based on their findings and a consideration of job creation dynamics as well as technological and other obstacles to implementation, the study concludes that the challenge of new automation technologies is not overall job loss.[8] Rather the challenge results from compositional shifts in labour demand away from lower skilled and towards higher skilled workers, highlighting the need for education and skills policies and other policies to address inequality.

Worth highlighting are two empirical studies of the employment impacts of new automation technologies – specifically, industrial robots – that take different approaches to the prior studies that do not preclude job creation dynamics by construction. The first of these studies uses an industry-level robotics dataset to estimate the impact of the implementation of industrial robots on wages, productivity and working hours from the 1990s to 2007 in an econometric analysis of 17 developed countries.[9] The study finds that more robots are associated with higher productivity and wages.[10] Though the study does not find a statistically significant effect on total working hours, it does find some evidence that robots reduce the hours of lower- and middle-skilled workers, consistent with the concerns of the prior studies regarding the effects of new automation technologies on inequality. Another study also undertakes an econometric analysis using the same industry-level robotics dataset over the same period to evaluate the impact of industrial robots on local US labour markets. In decided contrast with the prior study, this study finds that more robots are associated with lower wages and employment.[11] As the two studies evaluate different regions (the US being one among 17 countries in the former) and employ different empirical strategies, it is not evident how to reconcile their contrasting findings, though additional studies of countries that have been in the forefront of robot implementation, such as Germany and Japan, may be helpful in this regard.[12]

Competing dynamics at different levels of aggregation

Much of concern about new automation technologies and jobs is based on a narrow emphasis on *substitution* effects at the task level, but technology affects jobs no less importantly through *complementarity* effects, *market expansion* effects, *income* effects and *input-output* production linkage effects with associated *income-induced* effects. These effects can play out in different directions at different levels of aggregation, that is, at the *task*, *enterprise*, *industry* and *economy-wide* levels, such that negative substitution effects at the task level can be offset by, for example, positive complementarity and market effects at the enterprise and industry levels. These dynamics can also play out over different time frames, creating challenges of transition even in the absence of overall job loss in the medium and long run.[13]

A useful illustration of job creation and destruction dynamics is provided by a study describing how the implementation of automatic teller machines (ATMs) affected the number of bank tellers.[14] The number of ATMs increased four-fold from 1995 to 2010, while the number of tellers per bank branch decreased by about one-third. If one only looked at substitution effects at the task level, one would inevitably conclude that the overall number bank tellers declined, as ATMs took over bank tellers' task of disbursing cash. Yet on the contrary, the total number of bank tellers in the industry increased by about 10 per cent. The reasons are that while the number of tellers per branch declined, remaining tellers upgraded to providing services on loans, investments and credit cards, so-called "relationship banking." That is, there was an offsetting complementarity effect at the enterprise level, though only partial in that the number of tellers per branch declined. On top of this was a more than offsetting effect in that the implementation of ATMs contributed to reducing the costs of opening a branch such that the number of branches increased by about 40 per cent, a market-expansion effect at the industry level, with the net outcome of these combined effects resulting in an overall increase in the number of bank tellers in the industry. Yet there are additional effects outside the industry, insofar as bank tellers earned higher incomes as a result of higher skills, creating jobs through increases in aggregate demand. Finally, jobs are created in the construction and building materials industries to build new branches, and the resultant income streams spread across the economy, examples of input-output production linkage effects and income-induced effects.

The ATM example partly depends on the value customers place on face-to-face exchanges in service industries. However, there are comparable illustrations from manufacturing. The automotive industry, for example, has been the leading user of robotics. An important recent development in Mercedes-Benz and BMW is the use of collaborative robots, or "co-bots," smaller robots designed to work alongside workers. A study at a BMW plant found that assembly lines with co-bots working alongside workers are more efficient than teams of workers or robots alone.[15] A Mercedes-Benz factory also shifted to the use of co-bots alongside workers, after finding that this combination is better suited to accommodating the customized options demanded by customers.[16] One report indicates that co-bots are expected to very soon become the largest selling robots, facilitated by prices falling as low as 15,000 US dollars.[17] Co-bots provide a clear example of a complementarity effect of new automation technologies, in which an increase in the number of co-bots implemented is predicated on a proportionate increase in the number of workers working alongside them. As with the example of ATMs, additional jobs are created in the wider economy by constructing and servicing co-bots and training workers to use them as well as by resultant income streams.

Reshoring

A key concern for developing countries is the prospect of "reshoring," the opposite of offshoring, in which production particularly of labour-intensive manufactures shifts from developing back to developed countries. This would be enabled by new automation technologies being used in such industries as apparel and electronics that have provided developing countries strategic entry points into global markets. For example, the more readily and cheaply robots can sew clothes and assemble consumer electronics, the less readily can developing countries retain their competitive advantage resulting from lower labour costs, and reshoring would provide lead companies with the advantages of lower transport costs and closer proximity to designers and customers. Reshoring is particularly likely to harm women's employment prospects in developing countries, given their disproportionate concentration in these industries.[18] These concerns are heightened when one considers the figures for risk of potential automation in different occupations applied in first several studies cited in the section on recent empirical evidence.[19] For hand sewers, the purported risk of potential automation is 99 per cent, for sewing machine operators 89 per cent, and for electrical and electronic equipment 95 per cent.

Taking these figures at face value does not, however, adequately convey a sense of considerable technological bottlenecks involved. In apparel sewing, a key challenge in using robots results from the pliability of fabric, pieces of which need to be accurately aligned before they are sewn, something workers can readily accommodate but robots cannot. The technology to overcome these bottlenecks is currently being developed, but remains at a pioneering stage. For example, one company's robots have sensors and accompanying software to count the number of threads in fabric to enable precise sewing while another is approaching the problem by using chemicals to make fabrics temporarily rigid so that they can be handled by conventional robots.[20] While sewing robots make use of conventional fabrics commonly made of natural fibers, an alternative approach is the use of 3D printing of apparel and footwear using extruded synthetic materials, which effectively merges textile and apparel production. While 3D footwear is now made and marketed by leading sport brands, a key technological bottleneck for 3D apparel is the development of materials with comparable softness and breathability as conventional fabrics.[21] In the electronics industry, the use of robots is increasing rapidly, particularly for the production of components. Yet substantial technological bottlenecks remain to the use of robots in electronics assembly, regarding such operations as picking up the correct part among an assortment of parts and inserting small flexible parts into tightly-packed consumer electronics, challenges that are exacerbated by the short product cycles of such electronics.[22]

At present, the evidence does not suggest a strong trend towards reshoring.[23] At the same time, it would be rash to be dismissive of concerns over reshoring, for the costs and capabilities of new automation technologies are rapidly evolving while labour costs in many developing countries are rising. Should reshoring become a significant trend, developing countries will be faced with a new set of challenges, including the need to strengthen skills policies so that workers are employable in other activities and to increase aggregate demand to offset the decline in foreign direct investment. Substantial reshoring would further limit scope for development strategies of integrating into global supply chains and export-oriented growth more generally.

Closing considerations

This policy brief opened with the question of whether new automation technologies are fundamentally different from earlier automation technologies in having greater overall labour-displacing effects. One thing that seems clear is that many of the alarmist affirmatives to this question are based on an overemphasis on substitution effects at the task level and underemphasis or outright exclusion of other effects, as well as by equating the probability that a job *could be* automated with the probability that it *will be* automated and thus ignoring the considerations underlying profitable investment. Concern over the labour-displacing effect of new automation technologies also needs to be squared with the slow productivity growth occurring in many countries in recent years, not least the US.

There is also an ambiguity in empirical studies of the effects of new automation technologies depending on whether they estimate potential labour displacement at the level of jobs or rather working hours spent on readily automatable versus not-readily automatable tasks for a given job. We have presented evidence from the apparel and electronics assembly industries suggesting that these studies underestimate the technological bottlenecks to the implementation of new automation technologies. But whether or not one takes these estimates at face value, translating the share of working hours that are potentially automatable into the share of jobs that are potentially automatable is ultimately a contestable social rather than narrow technological consideration.

The tendency to answer the opening question of this policy brief in the affirmative may also be based on a bias of perception resulting from the anthropomorphic characteristics of many new automation technologies. That is, there is a sense in which computers think, and robots have jointed arms, sensors if not senses, can be mobile, and in the case of popular co-bots like Rethink Robotics' "Baxter" and "Sawyer," changing facial expressions. Thus it may seem that computers and robots, having human-like characteristics, are more readily able to replace workers. But this bias of perception has no bearing on job creation and destruction dynamics. Earlier technological revolutions in now developed world were characterized by sweeping automation in such "continuous process" industries as iron and steel, chemicals, paper and printing, and food processing, while the manufacture of products comprised of interchangeable parts was revolutionalized by the assembly line, and the introduction of new machinery and chemicals in agriculture contributed to a massive reduction of the number of jobs in agriculture.[24] Ironically, the labour-displacing effects of these changes may have been more dramatic because the technology involved did not so much substitute for workers as fundamentally transform the work process itself.

Considerable caution should be exercised in endeavouring to anticipate the possible job impacts of new automation technologies. For the history of technical change is marked by unintended consequences, both positive and negative, developments that were not foreseen by either inventors or the companies that marketed their innovations. As a general principal, the more flexible a technology, the greater the extent of unintended consequences, and flexibility is one of the defining characteristics of new automation technologies and digitally-driven technologies more generally. It poses a daunting enough challenge to deepen our understanding of the present of work in hopes of gleaning some key developments of the future of work.

If new automation technologies should come to result in sizable overall job losses, this is ultimately a challenge of how workers can equitably share in productivity gains through a combination of earnings and working time, with hourly increases in the former financing declines in the latter. Regarding working time, particularly relevant are propitious declines through later and more intermittent labour force participation as a result of more education and earlier exit from the labour force as a result of retirement while still able-bodied, as well as well as through shorter workweeks and more vacation time. These need not weaken workers' attachment to the labour force and the economic and social benefits that accrue from such inclusion, but rather alter patterns of work over the course of life cycles. Yet rising inequality and falling wage shares in much of the world suggests the policy challenges to such propitious declines in working time in the context of labour displacing technical change.[25]

Earlier technological revolutions occurred alongside growing numbers of jobs in the economy as a whole, and empirical studies – though still too few and ambiguous to provide a definitive assessment – do not provide a clear sense that this will be otherwise in the foreseeable future. Then as now, the challenge of technical change may not be so much whether there will be more jobs destroyed than created, but the facility with which workers are able to transition from old to new jobs in a period of rapid change and to equitably share in productivity gains. Then as now – and looking to the future – this in turn will likely depend on progressive education, skills, labour market and social protection policies and the bargaining power of workers.

Endnotes:

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[2] *ILO Director General. 2015. The future of work centenary initiative. Geneva, International Labour Office. Cf. Nübler, Irmgard. 2016. "Technological changes and work in the future: Making technology work for all", Future of Work Issue Note Series, No. 1. Geneva, ILO; Nübler, Irmgard. 2016. "New technologies: A jobless future or golden age of job creation? Research department Working Paper No. 13, Geneva, ILO; Mokyr, Joel; Vickers, Chris; Zierbarth, Nicolas. 2015. "The history of technological anxiety and the future of economic growth: is this time different?", in Journal of Economic Perspectives, Vol. 29, No. 3, pp. 31-50; Erik Brynjolfsson, Erik; McAfee, Andrew. 2014. The second machine age: Work, progress, and prosperity in a time of brilliant technologies. New York, W. W. Norton & Company; Ford, Martin. 2015. Rise of the robots: Technology and the threat of a jobless future. New York, Basic Books.*

[3] *Frey, Carl Benedikt; Osborne, Michael. 2013. "The future of employment: How susceptible are jobs to computerisation?", Oxford, Oxford Martin Programme on Technology and Employment, a revised version of which was published in 2017 in Technological Forecasting and Social Change, Vol. 114, pp. 254-280.*

[4] *Chang, Jae-Hee; Huynh, Phu. 2016. "ASEAN in transformation: How technology is changing jobs and enterprises", Bureau for Employers Activities Working Paper No. 9. Geneva, International Labour Office.*

[5] *World Bank. 2016. World development report 2016: Digital dividend. Washington DC, World Bank. Arntz et al. (2016, full citation below) refer to three additional studies that apply the Frey and Osborne (op. cit.) method to European countries.*

[6] *Arntz, Melanie; Gregory; Terry; Zierahn, Ulrich. 2016. "The risk of automation for jobs in OECD Countries: A comparative analysis", OECD Social, Employment and Migration Working Paper No. 189. Paris, OECD Publishing.*

[7] *McKinsey Global Institute. 2017. A future that works: automation, employment, and productivity. All of the studies surveyed in this section up to and including the McKinsey study rely on the "O*Net Online" database, which distinguishes between tasks and work activities as follows: "Tasks are specific work activities that can be unique for each occupation" whereas "Work Activities summarize the kinds of tasks that may be performed across multiple occupations". The database is available online at: https://www.onetonline.org/*

[8] *The non-technological obstacles referred to by the authors include preference for engagement with humans rather than robots as well as legal and ethical obstacles, such as liability in the case of accidents involving autonomous vehicles.*

[9] *Graetz, Georg; Michaels, Guy. 2015. "Robots at work", IZA Discussion Paper No. 8928. Bonn, Institute of Labor Economics.*

[10] *Robots can also improve the quality of work by enabling workers to shift from more menial and hazardous tasks, and there is evidence that they are associated with fewer industrial accidents. Chang, Jae-Hee; Rynhart, Gary; Huynh, Phu. 2016. "ASEAN in transformation: Automotive and auto parts: Shifting gears", Bureau of Employers' Activities Working Paper No. 12. Geneva, International Labour Office.*

[11] *Acemoglu, Daron; Restrepo, Pascual. 2017. "Robots and jobs: Evidence form US labour markets", NBER Working Paper No. 23285. Cambridge, Massachusetts, National Bureau of Economic Research.*

[12] *Graetz and Michaels (op. cit.) note that there are problematic discontinuities in the robot data for Japan and so this is not among their 17 countries.*

[13] *For valuable discussions on these issues, see Arntz et al. (op. cit.); Mokyr et al. (op. cit.); Autor, David. 2015. "Why are there still so many jobs? The history and future of workplace automation", in Journal of Economic Perspectives, Vol. 29, No. 3, pp. 3-30; Calvino, Flavio; Virgillito, Maria Enrica. 2017. "The innovation-employment nexus: A critical survey of theory and empirics", in Journal of Economic Surveys, doi:10.1111/joes.12190.*

[14] *Bessen, James. 2015. "Toil and technology", in Finance & Development, March, pp. 16-19.*

[15] *Tobe, Frank. 2016. "Why co-bots will be a huge innovation and growth driver for robotics industry", in The Robot Report, 7 April.*

[16] *Gibbs, Samuel. 2016. "Mercedes-Benz swaps robots for people on its assembly lines", in The Guardian, 26 February.*

[17] *Tobe (op. cit.).*

[18] *Kucera, David; Tejani, Sheba. 2014. "Feminization, defeminization, and structural change in manufacturing", in World Development, Vol. 64, pp. 569-582.*

[19] *These are the studies relying on the Frey and Osborne (op. cit.) method.*

[20] *Economist. 2015. "Made to measure: A robotic sewing machine could throw garment workers in low-cost countries out of a job", 28 May; Brewster, Signe. 2016. "A robot that sews could take the sweat out of sweatshops", in MIT Technology Review, 22 September.*

[21] *Hanson, Lydia. 2015. "3D Printing and the future of the apparel market", in Featured, 18 May.*

[22] *Bouchard, Samuel. 2014. "Industrial robots needed in electronics manufacturing – apply here", in Robotiq, 11 February; Luk, Lorraine. 2015. "Foxconn's robot army yet to prove match for humans", in The Wall Street Journal, 5 May.*

[23] *Cohen, Morris et al. 2016. "Off-, on- or reshoring: Benchmarking of current manufacturing location decisions", The Global Supply Chain Benchmark Consortium; "De Backer, Koen; Menon, Carlo; Desnoyers-James, Isabelle; Moussiegt, Laurent. 2016. "Reshoring: Myth or reality?", Science, Technology and Industry Policy Papers No. 27. Paris, Organization for Economic Cooperation and Development; UNCTAD. 2016. "Robots and industrialization in developing countries", Policy Brief No. 50. Geneva, UNCTAD.*

[24] *Chandler, Alfred. 1977. The visible hand. The managerial revolution in American business. Cambridge, Boston University Press.*

[25] *For an elaboration of these points, see the introductory chapter of Islam, Iyanatul; Kucera, David (eds.). 2013. Beyond macroeconomic stability: Structural transformation and inclusive development. New York and Geneva, Palgrave Macmillan and International Labour Office.*

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