Exploring the Impact of Robotisation on Economic Development

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ABSTRACT

This paper speculates about the impact of robotisation on the world economy in the next 20 years. It is argued that though robotisation of sectors destroys jobs and thereby unleashes recessionary tendencies, Artificial Intelligence (AI) enables entrepreneurs, managers and workers to make more efficient use of their time and thereby leads to an increase in time available for consumption. We highlight that in any given sector, robotisation spreads because of its greater cost efficiency as compared to conventional production. But this development by itself would lead to a decline in relative prices of products supplied by a sector and through income effects stimulate consumption. Thus, in the wake of robotisation, the recessionary tendencies emerging from the destruction of jobs are pitted against the expansionary tendencies emerging from AI facilitated increase in consumption time and the mentioned fall in relative prices. Therefore, both increased and decreased economic activity are possible but a boom is likely, given increase in demand for time and labour-intensive services. Generation of frictional unemployment with labour shifting from rapidly robotising sectors to others and possible burgeoning inequality would necessitate globally coordinated basic income schemes funded by a global robot tax.

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JEL Classification: *J23; J24.*

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Highlights of this paper

- The paper analyses the impact of robotisation on the world economy in the near future by looking at its impact on production processes and consumption levels.
- It provides useful recommendations for policy such as globally coordinated basic income schemes to deal with the frictional unemployment generated by robotization.

1. INTRODUCTION

An extensive review of empirical evidence reveals that robotisation, which can enable production without human interference, has led to job destruction in agriculture, manufacturing and a number of service sectors such as those involved in providing banking and financial services and trading of stocks. While such job destruction is expected to continue, the service sectors that remain largely though not totally unaffected relate to creativity, thinking outside the box and the domain of contemporary programmed software, the emotional aspects of human interaction, recognition of complex patterns, use of complex motor skills and sophisticated communication[1]: for example, the composition of high quality and varied fine art and literature, hospitality services, carpentry and like occupations, care giving and sports.

The objective of this paper is to speculate on the potential impact of robotisation, i.e., the development of artificial intelligence, on the world economy in the next 20 years. The impact cannot, however, be captured in terms of the trajectory of one variable. Important descriptors of economic development are trends in employment, income inequality across and within regions/nations, poverty and economic growth. The paper tries to generate analyses about the future course of all of these. The tools used are existing empirical and anecdotal evidence on the impact of robotisation and some analytical/theoretical logic, based on both existing models/frameworks and new concepts.

We are aware that a good number of excellent models exist in the literature[2]. These models make specific assumptions to gain deep insights into the impact of certain facets of robotisation. We refrain from model building as this paper tries to uncover all the major mechanisms of robotisation impacting the global economy. These are difficult, though may be not impossible, to capture through a single model. We hope that the very general and broad framework developed in this paper will serve as an input into rigorous, precise and policy relevant empirical and theoretical model building in the future.

This paper starts from the very basics. Section 2 discusses the meaning of terms such as 'robots' and 'artificial intelligence' (AI) on the basis of existing literature. Section 3 then looks at how robotisation/AI has already impacted and might impact production processes in various economic sectors. Section 4 then reviews the macroeconomic studies done till date on the impacts of robotisation. Sections 3 and 4 provide a stepping stone for the discussion in Section 5 which provides an analytically rich framework that takes into account four important factors: the direct destruction of employment; the facilitation of greater time for consumption and the resulting positive impacts on aggregate demand and, therefore, employment generation; the decrease in the relative prices of goods produced by robotised sectors; and the possible replacement of outsourcing by insourcing. Section 6 concludes and makes recommendations for policy.

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[1] For example, Brynjolfsson and Andrew (2014) discuss the communication skills of Siri, a digital personal assistant and find it to be quite average and confusing at times.

[2] For example, see Sachs, Benzell, and Guillermo (2015) and Mookherjee and Debraj (2021).

2. ROBOTS AND ARTIFICIAL INTELLIGENCE: CLASSIFICATION AND DEFINITION

AI endows machines with the power to replicate both human faculties, such as calculation, translation, speech detection and cognition, as well as non-human faculties, say satellite imaging[3]. Quite recently, humanoids have been developed which can emote, collaborate and interact socially with other humanoids as well as humans. The range of emotional and social ability and intelligence that humanoids display is, however, still significantly lower than that of humans[4]. It is quite clear from empirical research conducted by Deming (2017) and Hartley (2017) that jobs which require soft skills will probably continue to grow at a rapid rate whereas jobs which make use of technical skills will contract[5].

Robots can be considered as receptacles in which AI is stored. These, according to the *International Federation of Robotics* (IFR) are machines that are "automatically controlled, reprogrammable and multipurpose"[6]. They are different from other machines as they are aware of and can react to changes in the environment: a drone, classified as a robot, is capable of always landing safely without human assistance, unlike an airplane (Mitra & Mousumi, 2018). Unlike humans, robots are capable of working even in 24 hour shifts and can be reprogrammed easily to implement changes in manufacturing processes[7].

3. THE EMERGENCE OF AI AND JOB DESTRUCTION

Agriculture in developed countries has been highly mechanised for quite some time. Here robotisation /AI is currently being used to displace human participation in nuanced activities such as the harvesting of fruits and flowers, which require judgement about colour and texture to detect ripeness, and the pruning of vines[8]. This means that the number of agricultural jobs in developed countries has shrunk further from a level which was already low.

While it seems that agriculture in developing countries is much less automated than in developed countries, policy changes seem to indicate that job displacing automation and even robotisation might be on the anvil: for example, in India, the drawing up of the Model Agricultural Land Leasing Act, 2016[9] and a push given to contract farming through official legislation. Further, the Agricultural Produce Market Committee Act, 2003[10] which officially recognizes contract farming and provides a mechanism for resolving disputes in this regard, thus alleviating risks and enhancing engagement, will encourage consolidation of hitherto small agricultural holdings. Automation and robotisation may follow.

While there will surely be a reduction of employment opportunities in agriculture because of AI, it will facilitate micro level soil testing and very precise applications of fertilizers and water, as is being attempted by the *Australian Centre for Field Robotics*[11]. This will surely ramp up agricultural production and decrease consumption of chemicals

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[3] This definition is based on those given by Charniak and Drew (2009) and Simon (1995).

[4] As illustrated in Stéphane et al. (2016).

[5] Deming shows that the fast-growing cognitive occupations are those that involve 'fuzzy skills' i.e., understanding both human nature and bringing that understanding to bear on interactions. He also refers to Harvard labour economist Lawrence Katz's opinion that a really strong liberal arts education would be more valuable in the future as it might help students to deal with unstructured problems and new situations that cannot be dealt with by algorithms.

[6] Acemoglu and Restrepo (2017a); Acemoglu. and Restrepo (2017b).

[7] As reported in Ford (2015).

[8] Ibid.

[9] See Mani (2016).

[10] See Singh (2015).

[11] Ford (2015)

and their runoff into soil and water. Thus, technological changes would move in the direction of making food and other agricultural products cheaper and accessible for all.

In regard to the carrying out of routine operations in manufacturing, industrial robots, some with three-dimensional vision and others relying on precise timing of their movements, have been developed. It has been observed that such robots have been getting more and more efficient over time and will almost definitely surpass humans in shifting, packing and assembling objects. The use of such industrial robots has been growing over time.[12]

It is important here to point out the obvious: the impact of large and positive growth rates of the use of industrial robots on total human employment might not be very significant at present as the base population of robots is small; but these large growth rates will assume much higher significance in a decade or so as these will bring about a greater parity between the bases of robotic and human labour. This growing significance will then be manifested in a strong and growing adverse impact on human employment.

There are many reasons why employing robots in manufacturing will be preferable to humans: first, they are easily reprogrammable and as, mentioned, they can be effortlessly employed even in 24 hour shifts; second, they would eventually surpass humans in the speed of completing tasks; third, employing them is almost free of managerial issues such as dealing with feelings of dissatisfaction among human workers, unrest and the resulting implications for interruptions in work, and the need to look after the mental health of human labour. But most importantly it seems that the cost of training robots would be a fraction of the costs of training humans, given the need to handhold human workers with differential abilities to pick up new skills[13].

At present, there are many formal manufacturing activities which are untouched by robotisation even though these are machine driven. While robotised production does not require human intervention for significant lengths of time, other machine-driven activities are based on the active collaboration of man and machine. The role of humans in the case of robotised activities lies in programming robots and in switching these 'on' and 'off'.

It might be also the case that a robotised substitute for a human activity is available but is not being used as the former involves a higher average cost of production but again Moore's law[14], which refers to statistically observed and mainly software powered annual doubling of computing power, and the economies of scale associated with production of industrial robots might imply that this would no longer be the case in the future. This would result in a switch from human employees to robots.

On the other hand, informal manufacturing might continue without robots for some time as such manufacturing usually takes place through the efforts of the economically underprivileged who might not have access to credit and finance to incur the fixed costs associated with robotisation and are content with a low mixed income[15] for their toil. The mentioned changes in costs associated with robotised production however might imply that even the poor, in course of time, would prefer to buy cheap products produced by formal robotised manufacturing units. Clearly, this might further restrict the scope of informal sector production to just the provision of various kinds of services such as prostitution, low-cost massage services, care giving and domestic help. As we will see later, the scope for sale of these services might actually increase because of the implications of robotisation for 'consumption time'.

In regard to the formal service sector, the scope for robotisation is immense and we are only seeing the beginnings of robots displacing humans in this sector. These robotised services vary from those that prepare burgers from

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[12] The information in this paragraph is gleaned from Ford (2015).

[13] Discussion in this paragraph uses information provided by Ford (2015).

[14] A basic discussion of Moore's law is provided in Ford (2015) but a more detailed discussion is provided in Schaller (1997).

[15] A combination of wage, rental and profit incomes.

scratch; prepare, serve and charge sushi meals (Tabuchi, 2010); provide products ranging from DVDs to i-pads to cars through vending machines[16]; distribute medicines in pharmacies (Ford, 2015) and even to hospital rooms (King, 2010); and finally, those that replace the skill capabilities in middle level workers leading to the phenomenon of the 'missing middle'[17]. Further, computers/robots imbued with machine learning can allocate work to fairly highly paid consultants, learn by observing the action sequences leading to the completion of assignments, and thus successfully replace these highly paid white-collar workers (Ford, 2015).

In addition, mass online courses offered by academics of great repute are fast becoming popular[18]. These courses are often of very high quality and students in distant countries located in Africa, Asia etc. can benefit from these. It seems that even grading of questions might not be a problem because of machine learning replicating the way in which an instructor grades answer scripts. Yet examining students registered in a mass online course is still a major problem and the technology of monitoring these students when they take exams is far from perfect, leading to huge scope for people passing their exams using unfair means including the services of dummy examinees. There are other problems: lack of classroom interaction detracting from the ease of learning, as well as the reluctance of private universities, mentioned in Ford (2015), to subscribe to this model: if successfully implemented and used for providing degrees, mass online courses would result in a dwindling in the demand for instructors. While a significant use of mass online courses for awarding degrees will surely not take place in the short run it might become increasingly popular in the intermediate run, say 10-15 years from now. Thus, jobs in the education sector might become increasingly scarce in the intermediate run.

At present, major robotisation in the services sector is only occurring in the retail fast food sector, for example, McDonalds and other leading fast-food brands replacing human cashiers with automated payment kiosks[19]; and the retailing of branded products through means such as the use of very sophisticated vending machines; and for stock exchange negotiations[20]. But there could be a drastic change in this scenario. Robotic activity is picking up in the following sectors though humans still have a massive lead over robots which seems unlikely to be erased in the next 20 years: translation[21], writing of novels[22], news reporting[23], art[24] and composition of music[25].

Thus, even though robots are going to displace humans from jobs in many parts of the economy there happily are large sectors where employment would not be affected in the near future. Given the mentioned limitations of

[16] For details regarding the explosion in the vending machine industry see Semuels (2011); for a case study of movie rental kiosks displacing traditional movie rental stores such as Blockbuster through economies in the use of labour, see Ford (2015).

[17]Computers and the use of the internet have enabled high level white collar workers to perform the chores of communication, computation and accounting themselves. This phenomenon has been explained at length first by Autor (2010) and then by Jaimovich and Siu (2012).

[18] We use the contributions of Ford (2015); Salmon (2012); Selingo (2013) and Chafkin (2013) in this regard.

[19] Johnson (2018).

[20] Automated trading algorithms, as of 2015, were responsible for nearly 66% of stock market trades, and between 2005 and 2012 the average time taken to execute a trade dropped from about 10 seconds to under one thousandth of a second (Ford, 2015).

[21] Refer to Hicks (2018).

[22] See Schaub (2016)

[23] Softwares such as *StatsMonkey* (for sports journalism) and the more widely applicable, *Quill* and *Heliograf* have already demonstrated their capacity to construct news stories. For more discussion see Carr (2009); Ford (2015) and Moses (2017).

[24] For example, a software called *The Painting Fool*, as discussed in Ford (2015) and Shubber (2013), can identify emotions in photographs of humans and use these as inputs into abstract paintings.

[25] Artificial Intelligence, as of today, can compose music. For details see Smith (2013) and Ford (2015).

humanoids, humans would still be required in the hospitality sector: in hotels, restaurants and as tour guides. Similarly, robotic substitutes for care givers who perform a number of functions at the same time for the elderly[26] have not been invented.

4. EMPIRICAL STUDIES ON THE MACROECONOMIC IMPACT OF ROBOTISATION

Consider the study of the US and Western Europe by Acemoglu and Restrepo (2017a); Acemoglu. and Restrepo (2017b). In working out the impact of robotisation on the labour market the authors use the IFR's definition of robot: "an automatically controlled, reprogrammable, and multipurpose [machine]". Note that industrial robots are machines which do work that has previously been performed by manual labour -- such as welding, painting, assembling, handling materials, or packaging -- through limb movements. Thus, software and associated hardware which substitute for purely cerebral work are left out of the analysis. To that extent the impact of artificial intelligence on the labour market has been underestimated.

Using IFR data, the study points out that in 2007 the number of robots in use in the US and Western Europe was four times that in 1993; the average annual growth rate of employment of robots in 1993-2007 was thus a staggering 10.4%. IFR also estimates that there were between 1.5 and 1.75 million robots in operation in this region in 2017. According to Boston Consulting Group this number could increase to 4 - 6 million by 2025. Thus, according to this estimate, the lower bound for annual growth of employment of robots in 2017-2025 is 10.88%. If robots can be considered a perfect substitute for humans in certain sectors, then one can consider aggregate labour in use in any economy to be a weighted average of the levels of robotic and human employment. Unless we assume a major increase in the growth rate of requirement for such aggregate labour the fact that the trend growth rate of employment of robots is around 11%, far greater than the current growth rate of human employment, implies that the growth rate of human employment has to go down in the future. Thus, clearly, *ceteris paribus*, we should expect the incidence of unemployment in the world to rise significantly as a result of the introduction of industrial robots. The use of artificial intelligence in substituting for white collar work in a wide variety of service sectors should further exacerbate this trend.

In the mentioned study of the United States (Acemoglu & Restrepo, 2017a) the authors consider the impact of increase in the number of industrial robots on human jobs in 1990-2007 by looking at the direct displacement of humans by robots; as well as the stimulus provided by the associated increase in productivity to a) various parts of the local economy to which industrial robots are added and b) the national economy of the United States. Also considered is the impact of reduced employment in the robotised sector on wages and employment in other sectors: one can expect the impact on wages to be negative, thus incentivising certain non robotised sectors to hire more people. After accounting for all these effects, the study uses a measure of the exposure of each local labour market to robotisation[27] to find the effects of variability in such exposure on wage rate and employment. This study establishes that the introduction of a new robot per 1,000 workers in a commuting zone reduced the local employment-to-population ratio by 0.16 percentage points and local wages by 0.25%. This is equivalent to 3 workers losing their jobs to every robot.

Data from the World Bank Jobs Database reveals that the number of employed people in the United States and Western Europe in 2013 was 147.3 and 173.9 million respectively, totalling 321.2 million. Assuming a growth by

[26] Administering medicines; providing comfort and company; and physically lifting and moving geriatric people.

[27] This is defined as the weighted average of penetration of robotisation in national industries, the weights being the corresponding employment shares in the local labour market.

10% in the period, 2013-17, this yields a total employment of 354 million in 2017. The lower bound of the Boston Consulting Group's estimate of increase in the number of robots during 2017-25 is 2.25 million. This implies that in the period 2017-25 employment growth in United States and Western Europe would be reduced by 6.75 million which is equivalent to around 1.9% of the current level of employment. This is significant but not too large. If we take the upper bound of the BC group's estimate then the number of robots installed would be 4.5 million, thus robbing the economies of United States and Western Europe of as many as 13.5 million jobs. This is not only significant but quite large as it amounts to around 3.8% of current employment. Note that the time period that we consider in this paper is 20 years; by 2038, the share of robotic employment in total employment could well climb to 10%.

Moreover, the estimate of the authors of "one industrial robot destroying three jobs" could be considered an underestimate as they do not consider the adverse impact of job destruction on aggregate demand and through it the demand for human and machine labour. Further, in the future, both the software and hardware associated with industrial robots is surely going to improve, as already discussed. This is surely going to cause an increase in the job displacement potential of an installed robot.

In regard to developing countries, the ILO Bureau for Employers' Activities together with the ILO regional office in Asia and the Pacific have extensively researched the subject of the impact of automation and AI on employment in the ASEAN region. Five major sectors were studied: automotive and auto parts; electrical and electronic parts; business process outsourcing; textile; clothing and footwear; and retail. The study also included a detailed survey which led to 4,076 responses from ASEAN enterprises in the manufacturing and service industries as well as 2,747 responses from those engaged in university and technical education.

In addition to all this, there were 50 interviews with key stakeholders in ASEAN countries as well as validation exercises with executives in Cambodia, Indonesia and Singapore. This project by the ILO fed into a series of papers, the most pertinent of which is entitled *The Future of Jobs at Risk of Automation in ASEAN* (Chang & Huynh, 2016). This is a result of a test study which applies research methodology developed by Carl Frey and Michael Osborne of the University of Oxford. The method is used to analyse the susceptibility of various occupations to automation in the ASEAN region.

While ASEAN is a very tech savvy region with most of the population using mobile connectivity, it has not been at the forefront of technological innovation. Rather the economic progress in ASEAN countries has been based on technological adaptation. Some of the more backward countries among the ASEAN specialise in labour intensive manufacturing and the outsourcing work given to it by the developed countries. The growth of labour-intensive industry might become a victim to automation and progress inside developed countries such as the United States where it is now possible for a single robot to complete the entire process of manufacture of products such as garments from fabric[28]. Thus, insourcing might replace outsourcing.

Frey and Michael (2013) estimated that 47 per cent of jobs in the United States were at high risk of computerization within two decades. In the mentioned study, which uses the same methodology, five ASEAN countries -- Cambodia, Indonesia, the Philippines, Thailand and Viet Nam - are analysed. The study concludes that 56 per cent of all employment in the ASEAN-5 is at high risk of displacement over the next decade or two.

Across ASEAN-5 countries, industries that have been identified as having high potential for automation are hotels and restaurants; wholesale and retail trade; and construction and manufacturing. The study concludes that industries with low automation risk across the ASEAN-5 include education and training as well as human health and

[28] This is the case of the *Sewbot*, the robot that converts fabric to garment much more efficiently than humans. For details see Device Plus (2018) and Zhou and Zhang (2017).

social work. However, Ford (2015) shows that technologies are available for the mass dissemination of high-quality education and grading which are potentially 'human capital displacing'. This phenomenon though, as pointed out, might not take place in the short run. The key question is whether educational institutions will adopt such technology. If Western universities offer mass online courses, awarding degrees and diplomas, for students in the ASEAN, a lot of employment in the education sector in ASEAN will be displaced.

The occupations that have been judged to be at most risk of automation are garment production in Cambodia, an occupation which dominates the national manufacturing sector and employs close to half a million sewing machine operators; retail in Thailand involving one million shop sales assistants; and clerical work in Indonesia which employs about 1.7 million office clerks.

Much more alarming are the developments in China which has in the recent past been the supplier of a very large chunk of the world's factory labour. But it seems that in trying to ramp up its production of various commodities it has decided to tackle the problem of rising human wages, which is inevitable when demand for human labour increases because of an increase in consumption demand, by substituting human labour with robotic labour /AI. This process has been encouraged by the extremely fast paced developments in robotics/AI in the past two decades: robots and computers are becoming more efficient and this increase in efficiency is taking place at a rapid pace. It is important not to characterize this shift from human to robotic activity in China as an official response to increasing wage rates of human labour. The shift has occurred as a result of the responses to rising wages of a) large international corporations with factories in China and b) indigenous firms located in China supplying to these companies or directly to the domestic and international markets.

China accounts for an extremely large proportion of the use of the world's industrial robots: in 2014, Chinese factories accounted for about 25% of industrial robots the world over. Moreover, there was a 54% increase in the number of industrial robots in use over 2013-14. This clearly points to rapid robotisation resulting in job losses for human labour in the absence of matching economic growth. A specific example illustrates this conclusion: in 2015 *Midea*, a leading manufacturer of home appliances in the heavily industrialised province of Guangdong, planned to replace 6,000 workers with automation by the end of the year (Ford, 2015).

Job displacement in regard to blue collar work is not being adequately neutralized by the creation of white-collar opportunities. In mid-2013, Chinese government statistics revealed that half of the country's current crop of college graduates remained unemployed. While some of this unemployment can be explained by the time-consuming nature of job search, official statistics also indicate the persistence of such unemployment: in 2013, more than 20% of the previous year's graduates remained unemployed (Ford, 2015). As development of software and artificial intelligence continues to take place at a rapid rate it is unlikely, given existing demand conditions, that enough white-collar jobs will be created in China to neutralise the effects of blue-collar job decimation. In fact, there might be a net decrease in the number of white-collar jobs over time unless drastic changes are catalysed through government policy in the occupational structure or there are some unanticipated shifts in demand.

The trends in employment growth in India do not present a rosy picture, as depicted in Abraham (2017). The annual rates of employment growth in the periods 1999-00 to 2004-05, 2004-05 to 2009-10, and 2009-10 to 2011-12 have respectively been 2%, 0.7% and 0.4% respectively. An exercise using different sources of data reveals negative growth in the period, 2013–14 to 2015–16, which can be majorly attributed to significant negative growth in the construction, manufacturing and information technology/ 'business process outsourcing' sectors.

There has been no comparable slowing down of growth of GDP over this period, thus indicating a marked substitution of labour by capital. Clearly, this phenomenon of negative employment growth might continue; if robotisation gets mainstreamed in the Indian economy then the magnitude of the already negative employment growth rate might become larger. There is enough evidence to show that computerized automation is not new to India and evidence of its use is available in research done 20 years back (Narain & Yadav, 1997). Large scale robotisation is logically the next step. In fact, in the healthcare sector, humanoids have taken their first hesitant steps (Rohit, 2018). But it is the automobile industry which is turning out to be the leader in regard to robotisation (Rais, 2019). In 2019, IFR reported of a 30% increase in India's use of robots. Much of this increase in demand was driven by robots being included in the production processes of manufacturing plants to enhance productivity as well as the quality of vehicles. Robots are being used to perform tasks such as painting and welding while human labour is being deployed to perform tasks that require more skill. Leading users of robots in India include Maruti Suzuki India (5000 robots in its plants), Ford Motor Company (450) and Hyundai Motor Company (590 Generation 4 robots).

Africa, which at last seemed to be ripe for industrialisation and development of the formal sector through employment of humans, has evidently embarked on a path of expansion of the non-agricultural sector through robotisation. Clearly, industrialisation has come to Africa at a stage when robots that outperform humans in regard to several tasks have been invented, as documented by Rodrik (2016) and the World Bank (2016).

Clearly it seems that barring major changes in the demand scenario, robotisation would pose a potent threat to human jobs. Some minor sources of increase in demand have been accommodated by Acemoglu and Restrepo (2017 a and b) but clearly this is not enough to convince anybody that the gloomy picture emerging from the trend analysis will brighten considerably. However, in the next section, we introduce a major implication of robotisation/AI on the demand side which may lead to the conclusion that the prophets of doom might be mistaken.

It would be pertinent in this regard to analyse the labour intensity of production of robots (see Felderman (2019)) themselves. Humans do play an important role in the manufacture of robots. After all, robots are designed and programmed by humans and this process can take a long time if the objective is to manufacture a robot that relieves a human from performing a complex task. Robots house brain like components known as microcontrollers for perceiving the environment and responding to it appropriately through directions given to body parts; programming and designing microcontrollers and body parts to ensure correct perception and optimal response is the domain of humans. However, it deserves mention that once a programme and design is generated for a single type of robot it can easily be used to manufacture scores of robots of the same type. The process of fabrication and putting together of body parts is the meaty part of manufacture of robots. From all indications, this is performed partially by humans and partially by robots and is not very labour intensive: for example, consider a plant in Oshino, Japan where industrial robots produce industrial robots, supervised by a staff of four workers per shift (Tilley, 2017).

The number of hours it takes to design and manufacture a batch of identical robots seems to be vastly less than the number of hours of service the batch would provide to their buyers: for example, a typical robot manufactured by FANUC Corporation provides 80,000 to 100, 000 hours of uninterrupted service (Motion Controls Robotics). Given that the cost of material inputs used in a robot is significant and it typically runs on electricity, the number of hours needed to build a robot has to be fairly less than the number of hours for which it can be used for such use to be profitable, as revealed by the observed substitution of human employees by robots.

That robots displace much more human labour than is used up in their manufacture and design and are therefore important forces reducing human employment is an important observation. At the same time, it should be recognized that robot making companies are important generators of revenue, some of which can surely be taxed to benefit the unemployed. In 2019, Mitsubishi Electric was the leader in the production of industrial robots in the world with a revenue of 11.35 billion Euros; ABB robotics was a distinct second at 5.27 billion while other companies were very far behind (Statista, 2021). The combined figure of 18.62 billion Euros indicates the huge revenue generating capacity of robot production – a channel which will not dry up in the near future as the increase in robot use shows no signs of decelerating.

5. THE FUTURE OF ECONOMIC DEVELOPMENT AS A RESULT OF ROBOTISATION: AN ANALYTICAL APPROACH

As robots become more efficient than traditional production using men and machines as close complements, it would make sense to expect capital to move from the traditional sector to the robotized sector because of higher returns. This will result in labour in the traditional sector becoming less productive. However, employers will most probably not reduce the money wage to maintain full employment in the labour market. Instead, downward money wage rigidity, as assumed by Keynes (1936) and explained by others as resulting from the need to keep worker morale high would be associated with laying off of workers: it is better to keep the morale of a diminished work force high, following decline in demand, rather than pay an undiminished work force a lower wage and lower morale[29].

It would be natural to assume that enterprises laying workers off will lead to massive recessionary tendencies in the economy. As workers get laid off it is very likely that aggregate demand will decline in a version of our story in which the increase in aggregate demand produced by a decline in relative prices of the products of robotising sectors is overwhelmed by the recessionary impact of technological unemployment. This in turn leads to more unemployment. Thus, the economy might be caught in a recessionary spiral: owners of capital might allow much of the capital in traditional production to become obsolete since they would be able to meet all of their needs plus the needs of a declining number of employed workers by using only robots and just a part of the traditional machinery. In course of time, the capital stock might shrink and the economy would decline to a low level of aggregate income with a large mass of unemployed workers.

However, the likelihood of this gloomy story is diminished if we consider that consumption is often a function of availability of time. We argue that it is highly likely that robotisation will provide more time to owners of capital as well as their employed workers to consume: for example, executives might no longer need to write standard emails as these could be written by their AI assistants; the time spent by managers in supervision of staff would be greatly diminished as the number of human staff in an organisation would decline; similarly, collation and filing of information would automatically be done by sophisticated software programmes.

Thus, there is a very strong possibility that the length (in hours) of the work week would decline. In reality, the length of the work week has been on the decline in many countries for quite some time, as illustrated by Konnikova (2014). There is hardly any evidence to clearly identify technological progress, especially that in the realm of AI, as the primary cause for decline in length of the work week. But it can be argued that such technological progress provides greater freedom to worker welfare-oriented legislators and norm setting organisations. Moreover, firms might autonomously decide to reduce the length of the work week for certain types of workers made more efficient by AI.

When entrepreneurs, workers and managers work less they will have more leisure to consume hitherto under consumed goods and services, a few examples being tourism, paid companionship, wellness services and various forms of entertainment. In the economics literature, consumption has not been modelled as requiring time. But it obviously does for material objects such as apples, pieces of cake and books as well as the mentioned services.

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[29] Explanation of downward wage rigidity on the basis of work morale has been provided by Slichter (1920); Slichter (1929); Solow (1979); Akerlof (1982) and Kube, Maréchal, and Puppe (2010).

Thus, it would seem logical to expect that there would be a massive spurt in the demand for products and services whose consumption is time intensive. Many of these products, such as those mentioned in the last paragraph, would be those whose creation would be intensive in human capital. The employment thus generated will increase the demand for products of robotising as well as traditional sectors, leading to a propensity for a boom counteracting the initial tendency for contraction of employment and national income. An expansion of employment and economic activity in the next 20 years is thus not only possible but very probable. It may be conceded though that our insights cannot rule out a contraction which is, however, quite unlikely.

At the same time, we can be reasonably sure that significant pain will be caused to human workers moving from robotising sectors to other sectors as the movement will take time to complete and be associated with search unemployment; it is also possible that effective loss of human capital will be associated with a loss in individual incomes. For example, consider a qualified software consultant who is rendered unemployed and is forced to become a manager of a small spa. In such a case, carefully accumulated human capital would be rendered redundant. Moreover, the highly variable and random pace of innovation points to the possibility of a bulge in search unemployment of those seeking new jobs in a scenario of job destruction accompanying creation. This might give rise to significant and dangerous recessionary tendencies requiring prompt government action.

An obvious antidote to bulging search unemployment and declines in individual income is a national tax on robotised production to fund basic incomes for people rendered unemployed by it. The effectiveness of this instrument is questionable: a significant tax can lead to capital flight and would do nothing to solve the problem of cheaper goods produced by foreign robots destroying markets for domestically produced goods and thus, domestic jobs.

A better alternative would be the creation of a global fund for basic incomes financed by a uniform global robot tax. It is very likely that governments of affluent countries, the hubs of robotic activity, would insist on basic incomes that are indexed to national per capita incomes. A basic income scheme would also stimulate consumption demand and thus both incomes and employment, assuming that those taxed have a lower propensity to consume than those receiving the proceeds of such taxes.

Inequality in the income distribution will increase as robots displace white collar staff: as mentioned, teams of white-collar consultants would be rendered redundant by machine learning systems picking up their skills; as humans employed by a corporation in non-managerial roles declines, a thinning of the managerial cadre would also follow to accentuate job polarisation that has taken place over the last couple of decades. Thus, the "missing middle" in the income distribution might expand with incomes of owners of capital and entrepreneurs, corporate chiefs and very creative people such as novelists and actors located to the right and others to the left. Interventions by global and national governments to impose taxes on those to the right and encourage ownership of capital, through purchases in the stock market, by those to the left can lead to alleviation of inequality.

Our speculations thus far have mainly been for the case of a closed economy. Almost all economies in the world are open. Robotisation might lead to significant insourcing replacing outsourcing: it would make sense for corporations to open robotised plants close to developed country populations/labour forces characterised by high per capita incomes and high wages and shut down their plants in developing countries previously used to supply developed country markets. In the next 20 years, therefore, there could be major problems in regard to generation of employment and incomes for countries such as Cambodia, Thailand, Vietnam and even India. The only positives for such developing countries would be the import of cheap goods produced through robotised means tending to bring about a sharp decrease in the cost of living, and increase in consumption time for the AI aided workers and managers in the corporate sector and government offices.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

In this paper we look at the impact of robotisation in the next 20 years or so. After reviewing empirical evidence, we conclude that robotisation will lead to job destruction in agriculture, manufacturing and a number of service sectors such as the corporate sector involved in providing banking and financial services, restaurant services, trading of stocks and journalism. The service and goods sectors remaining largely unaffected would be health, those that relate to creation of fine arts and books, and hospitality services including labour intensive services involved in tourism, spa facilities and companionship. In the near future, workers with soft and fuzzy skills would face a high demand for their services but those with skills that are primarily technical in nature would be less secure.

It is argued in this paper that though robotisation of sectors destroys jobs it leads to an increase in the amount of time available for consumption by AI aided owners of capital, managers and workers. This in turn stimulates consumption of hitherto under consumed products, especially those goods and products characterised by time intensive consumption. As a result, both increase and decrease in national income/employment are possible as a result of robotisation. However, as the mentioned time intensive products are also labour intensive a net boom in employment and economic activity is highly probable.

In the developing countries the channels affecting employment and national income in the wake of robotisation are somewhat different: a decline in employment from activity outsourced by the private sector in developed countries due to insourcing; a fall in prices of robotised goods which would stimulate consumption on its own; and enhanced 'consumption time' which would lead to increased consumption of labour-intensive products and stimulate employment. Again, the possibilities of increase/decrease in national income and increase/decrease in employment exist. However, given the smaller formal sector in many developing countries, the aggregate enhancement of consumption time due to robotisation would be smaller and therefore the chances of a recession higher unless interventions to shore up demand through a minimum income scheme, as mentioned below, are implemented.

In the cases of both developed and developing countries there would be a lot of frictional unemployment with labour shifting from the robotised sectors or those undertaking outsourced activities to un-robotised sectors or those not involved in outsourcing. Governments and world organisations such as the World Bank have to ensure that such movers are nursed during their period of unemployment by a basic income scheme funded out of a globally administered robot tax as unilateral taxation by a country would be expected to lead to capital flight and therefore should be avoided.

In conclusion, artificial intelligence has the characteristics of a global bad and at the same time it displays the properties of a global good. The challenge before the world is to retain what is good while avoiding the mentioned undesirable outcomes through schemes that provide succour for those rendered unemployed and impoverished.

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