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Tax on robots: Whether and how much

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Abstract

This paper reviews the literature on the socioeconomic effects of tax on robots in order to find an answer to the question whether and how robots that replace routine jobs should be taxed. Although the rapid pace of automation may destroy many jobs, lead to a dramatic increase in income inequality, and result in revenue losses for the government, there is no consensus among economists on whether government intervention is necessary. One strand of economists argues that taxing robots would be a self-defeating act that would spur innovation and slow technological progress, while job losses from the use of robots by foreign competitors could occur anyway. However, another strand of economists that seems to be gaining ground argues for public intervention and the imposition of some kind of tax on robots or the work performed by robots. The first reason is that by taxing robots, governments will be able to generate tax revenue to offset the declining revenue from taxing labor as human labor is displaced by machines. The second reason for taxing robots is to prevent or limit income and wealth inequality that arises from potentially increasing inequality among the types of workers affected by automation and from the transfer of income from workers to owners of capital. Despite the consensus on the need for some kind of tax on robots, however, there is not yet agreement on the precise framework of tax policy. In general, policy proposals fall into two categories. The first advocates direct taxation of firms that benefit from automation, while the second proposes indirect taxation that does not tax firms directly to avoid potential stagnation of innovation. In the second proposal, the tax would be levied on the use of robots rather than robots, so that firms would pay for the negative externalities of using robots instead of humans. An optimal robot tax in our view would be levied similarly to a VAT tax on robot activities, with a tax rate that decreases with the age of the robots. In any case, the introduction of a robot tax requires a coordinated approach between countries, otherwise there is a risk that countries will lose tax revenues due to tax competition.

JEL: H21, O33

Keywords: automation, robots, optimal taxation.

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1 Introduction

With the development of technology, companies introduce new methods of production, markets expand, and businesses evolve. Companies rely on new technologies to better utilise capital, overcome information barriers, and innovate (Abbott & Bogenschneider, 2018). Over the last century, robots have replaced workers in many tasks as recent innovations in the form of robotic process automation tend to replace human performance rather than supplement it (Huettinger & Boyd, 2019).

According to Thuemmel (2019), empirical studies examining the impact of industrial robots conclude that they lead to productivity gains and job losses related to routine activities. However, their combined effect on the labour market is not yet clear: robots may contribute to reducing the employment rate, but they also have the capacity to offset this effect by stimulating growth in other sectors (Durán-Cabré, 2019). For instance, Acemoglu and Restrepo (2019) emphasize reinstatement effect of technology, where labour is re-established in a broader range of tasks, thus increasing labour share and labour demand.

Lower costs of using robots are particularly at risk for workers performing low-skilled routine tasks, as these occupations are the most open to automation (World Bank, 2019). Robots can undertake tasks of unskilled (usually routine) workers and complement tasks of skilled (non-routine) workers. Autor and Dorn (2013) describe a structural change in the labour market with decreasing numbers of middle-income manufacturing workers in favour of low-income service workers. The rationale behind the change is the supposed lower susceptibility of manual tasks of service occupations to computerization due to higher flexibility and physical adaptability. Robots, however, are not replacing only industrial workers, but are increasingly used in service sectors. There is a notion that nowadays robots are slowly becoming lawyers, doctors, bankers, social workers and nurses (Daubanes & Yanni, 2019; Oberson, 2019).

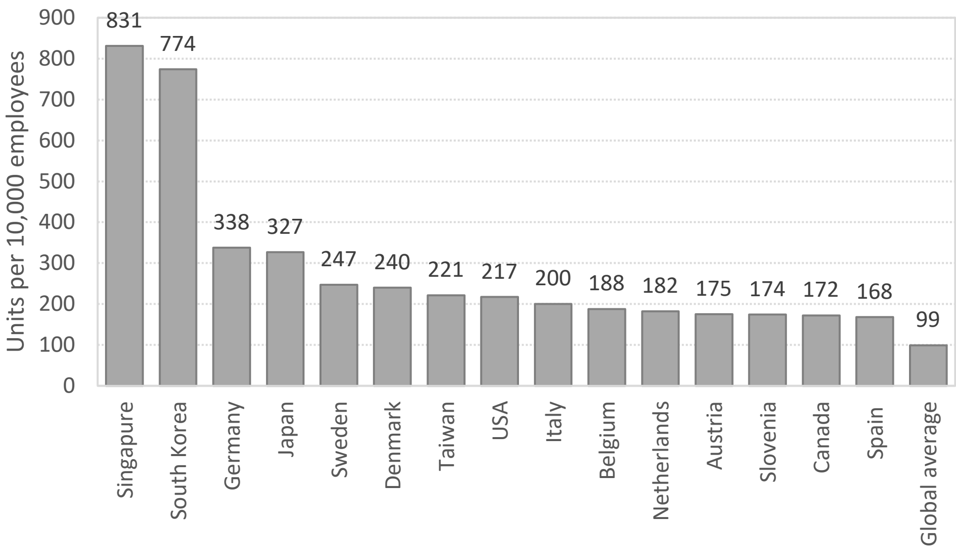
Discussions about the future of work are dominated by fears of unemployment due to the use of robots, especially in the industry, what economist John Maynard Keynes would designate as “technological unemployment" (Abbott, 2020). In a recent study, Frey and Osborne (2017) find that almost half of the US employment is at risk due to computer-controlled equipment. According to their predictions, the most exposed industries are transport, logistics and administration (McCredie et al., 2019). Recently, Acemoglu and Restrepo (2020) estimate for United States that additional robot per thousand workers lowers the ratio of employment to population by approximately 0.2 percentage points and wages by 0.42 percent.

The decline in industrial employment has been an established trend in recent decades in some high-income economies (Republic of Korea, Singapore, Spain and the United Kingdom), but it mainly reflects the shift from production to services sector as manufacturing productivity increases. In contrast, millions of industrial jobs have been created in developing countries (i.e.

Cambodia and Vietnam) since the late 1980s, and the share of industrial employment has remained stable on average, despite numerous forecasts of job losses due to technology (World Bank, 2019).

The number of robots operating around the world is growing rapidly. By 2019, 1.4 million new industrial robots are predicted in operation, which means total 2.6 million robots worldwide. More than two-thirds of robots are employed in the automotive, electrical/electronics, and metal and machinery industries. The density of robots per worker in 2018 is highest in Singapore and South Korea. With less than half of robots Germany is the most automated country in Europe (ranking 3rd worldwide), followed by Sweden (5th), Denmark (6th), Italy (9th) and Belgium (10th). Among the eastern European countries, the most automated country is Slovenia (174 units, ranking 13th in the world) (Statista, 2020; World Bank, 2019; IFR, 2020).

Figure 1: Number of installed industrial robots per 10,000 employees in the manufacturing industry, top 15 most automated countries, 2018

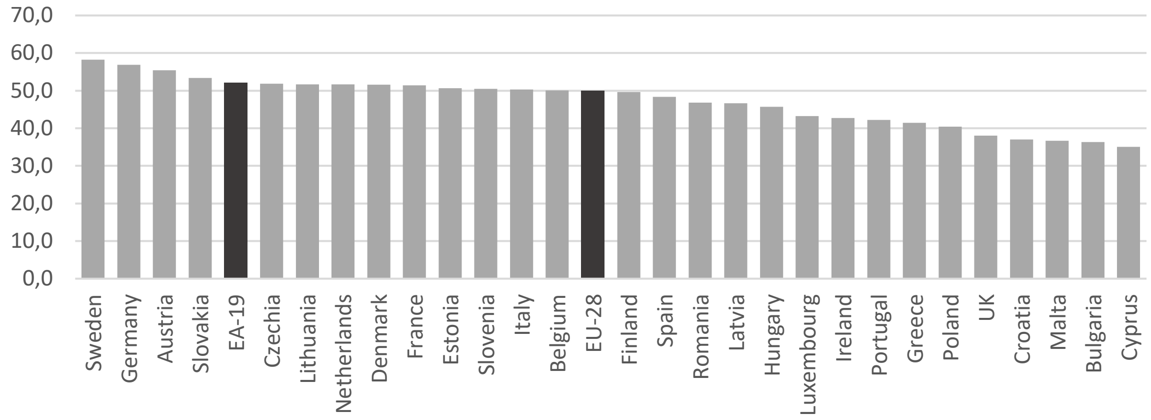


Source: Statista, 2020

Interestingly, despite the high prevalence of robots, the employment rate remains high in these countries. According to Dauth et al. (2017), automation can affect young workers more than older workers. Although the adoption of robots did not have a significant net effect on employment in Germany, it reduced the hiring of young participants. As a result, the effects of automation in ageing countries may be different from those with young population and a large number of new entrants to the labour market (World Bank, 2019). Arntz et al., (2016) found, studying EU data, that although technology may be replacing workers in some jobs, on overall it raises the demand for labour.

Nevertheless, the widespread introduction of robots based on artificial intelligence still raises growing concerns about the disappearance of jobs. If robots have a negative impact on the labour market and if massive jobs for people disappear in the future, there can be a multiple negative effect (Oberson, 2019; Durán-Cabré, 2019). First, significant tax and social security revenues could be lost if robots were associated with a high elasticity of substitution with respect to labour, which is undoubtedly important for public finances. Namely, labour taxes in general represent the main source of income in tax systems. In the European Union, the labour taxes represent half of all tax revenues and amount to 19.7% of GDP in 2018.

Figure 2: Taxes on labour as % of total taxation, EU countries, 2018



Source: https://ec.europa.eu/taxation_customs/business/economic-analysis-taxation/data-taxation_en

Second, the need for additional revenue would increase by countries to support the growing number of unemployed workers. Third, a reduction in labour income would also reduce consumption. Additionally, these would lead to an increase in inequality between rich and poor, as low-skilled and routine jobs are probably the most affected. To adequately face this issue, governments require increasing resources for the investments in education and training system (Bottone, 2018). Becker (2018) explains that wage losses which are consequences of increasing rationalization of jobs through computerization and use of machines, should be properly addressed by social policies through introduction of additional contribution to social security. Given the presented findings, the taxation of robots is seen as a possible instrument to mitigate these negative effects.

The rest of the paper is structured as follows. Section 2 presents arguments pro et contra robot taxation by discussing proposals why the robot tax is necessary and why robot tax could be associated with particular issues while Section 3 describes possible taxation method, tax base and tax rate. Last section concludes.

2 Arguments for and against the taxation of robots

There are two main narratives in the economic literature on technology, growth and distribution. One is that technological advances increase productivity and thus output per person. While there are some transition costs as certain jobs become obsolete, the overall result is a higher standard of living. This is an optimistic narrative that suggests that technology has more positive effects than simply displacing workers, as it increases worker productivity and raises demand for their services. Rising incomes then create a demand for various services and thus for labour (Berg et al., 2016).

The other is a more pessimistic narrative that focuses on the losers of technological progress. According to this narrative, the inequality that has increased in recent decades may be due to technological pressures, as the computer revolution in developed countries has contributed to lower relative demand for routine jobs. Also, in many countries, people with lower skills saw a relative decline in their wages (Berg et al., 2016).

Obviously, the main contribution of robotics and AI technology can be seen in the long run in an improved quality of life, as people are freed from hard manual work, which is often repetitive and intellectually not demanding. Robotics and AI technology increase technological productivity, and the loss of jobs resulting from the process of robotization may not be compensated by newly created jobs. Even for unemployed workers, retraining to meet the demands of the robotic economy can be difficult. According to (Ivanov, 2017), in the short and medium term (10 to 15 years), society will be faced with considerable technological unemployment and a disproportionate supply of human labour, which may even continue in the long term. In the earlier literature, some solutions to combat technological unemployment have been developed, such as a commitment to employment, government job creation, tax policies, financial incentives for job creation, etc. (Ivanov, 2017).

Different proposals for the robot tax have drawn interest among economists and opinion leaders. Regarding the topic, the focus has been mostly on economic and policy arguments for and against the taxation of robots.

2.1 Positive aspects of robot taxation

Proponents of the robot tax point to two main reasons for taxation. First, the generation of tax revenue to offset declining revenue from taxing labour, since robots are not subject to this type of taxation (Abbott & Bogenschneider, 2018). The growth of robotics raises concerns that governments will suffer a loss of significant amount of tax revenue with human labour being displaced by machines (Mazur, 2019).

In modern society, governments use taxes for three different purposes: to raise revenue for necessary government functions, to reduce inequalities in the distribution of income and wealth, and as a regulatory component to guide certain behaviour and promote economic stability. To achieve this, tax revenues must grow with the needs of population, be redistributed to those without income and be designed to benefit all and not just some (McCredie et al., 2019).

Increasing automation should thus be properly addressed from social policies since robots are recognized as a risk to full-time employment (Bendel, 2019). Certain ways in which technological innovation disrupts the labour market and thereby undermines the revenue base of governments are fairly straightforward to understand. Increasing automation through the introduction of new technological developments in areas such as robotics and artificial intelligence (AI) represents one of them. For example, when a worker is replaced by a robot, the government is no longer able to collect payroll taxes from the worker's employer or sales taxes on the worker's spent income. Moreover, even if firms earn higher profits from the use of the robot, the increased corporate taxes levied on those profits cannot fully offset the loss of employment taxes, as the corporate tax rates tend to be lower than employment tax rates (Johal et al., 2018).

In case in near future robotics and AI technology would create a technological mass unemployment and depress the wage share in national income, the governments, especially in social market economies would face huge challenges in sustaining existing social welfare systems as their fiscal capacity would be lost (Schattenberg et al., 2018).

Since the current social security system is financed on a pay-as-you-go basis, a reduction in the number of people in the labour force puts considerable pressure on the government budget. As the (human) labour force will decline, less employment tax revenue will be available for current retirees and the disabled. Government spending will continue to increase due to the increased need for benefit programs to assist the unemployed (Mazur, 2019).

If governments fail to find stable alternative sources of revenue, the situation with an increasing number of unemployed will force them to drastically cut social spending, which could result in their inability to maintain social policies. Failure to adequately address the new socio-economic situation would likely lead to a drastic increase in wealth and social inequality (Schattenberg et al., 2018).

To successfully restore their fiscal space, governments could move to greater taxation of capital income, wealth (financial or real estate), value added, and or consumption of luxury goods. As tax leakage occurs due to profit shifting, governments would need to improve tax coordination and international cooperation. Alternatively, they could introduce a "robot tax", which would be implemented as a special corporate tax linked to the use of robots and AI in the value creation process (Schattenberg et al., 2018).

Another alternative could be to tax a company's cost savings/profit increases due to the substitution of human labour. The introduction of such a tax could offset the social costs caused by the displacement effects of automation, although it would generally impose a burden on firms trying to achieve cost efficiencies (Schattenberg et al., 2018).

In general, the discussion presented points to the problem of the decline in the tax base due to the decline in labour income. Despite positive effects of automation on productivity and economic growth, most profit is captured as corporate profits or capital gains, both of which are subject to a much lower tax burden (Mazur, 2019).

The second reason for taxing robots is to prevent or limit income and wealth inequality. First is inequality between the types of workers affected by automation, since low-skilled, routine workers often have the most difficult situation. They are replaced by robots, decreasing their income, while high-skilled, non-routine workers supplement robots, increasing their income (Daubanes & Yanni, 2019; Naito, 1999). Moreover, the automation of tasks previously performed by workers contributes to their wages falling and the profits of robot owners rising, transferring income from workers to capital owners (Mazur, 2019).

Assuming that robots are almost perfect substitutes for human labour, the use of robots increases output per person, while on the other hand inequality increases. This is due to the increase in the supply of effective aggregate labour, which then translates into lower wages. Also, the increased profitability of investment in robots drives the shift from investment in traditional capital to investment in robots, which additionally reduces the demand for labour working with traditional capital such as buildings and conventional machinery (Berg et al., 2016).

As the supply of robots increases, the return on traditional capital increases. Combining traditional and robotic capital (e.g., warehouses with robotic shelf stockers) with diminishing help from human labour produces increasing output, leaving robots as mere producers without consumption (Berg et al., 2016).

According to Berg Buffie, and Zanna (2016) there are “four models of the short and long-run effects of robots on output and its distribution in a family of dynamic general equilibrium models”. For all four models, they found that robots increase productivity but also reduce wages. As output grows, wages fall, not only in relative terms, but also in absolute terms. In all countries, capital has a much more unequal distribution compared to income, and this will increase with the introduction of robots, further driving the unequal distribution of income (Berg et al., 2016).

As explained by Mazur (2019), the decline in wages is inevitable even if the introduction of robots does not eliminate routine and low-skill jobs. In order to keep their jobs in competition with robots who are more productive, always present and less costly, human workers will have to accept lower wages.

As also suggested by empirical evidence, higher productivity which is the result of the introduction of robots, may not result in higher workers' wages. Robots which represent a form of capital will likely create benefits of this new technology for their owners. Since capital is owned by wealthy this would additionally widen the gap between top one percent and rest of population (Mazur, 2019). In addition to the decline of routine cognitive and manual jobs, new forms of automation will also impact non-routine cognitive and non-routine manual jobs (Johal et al., 2018).

Another concern related to job losses due to automation is the uncertainty whether the number of new high-value jobs will be sufficient to compensate for the losses (Johal et al., 2018). Researchers differently predict the impacts of automation on jobs. Frey and Osborne (2017) expect that almost half of total employment in US is in occupations that would potentially be automated while Arntz et al. (2016) estimated that share to only 9 %. According to their study the share of workers whose automatibility is at least 70% is highest in Germany and Austria (12%), while it is lowest in Korea and Estonia (6%). Study of Chiacchio et al. (2018) focusing on 116 regions in 6 EU-15 member states finds that regions which were faster in robotization, experienced lower rates of labour force growth (Atkinson, 2019).

Whether automation will lead to fewer jobs in total thus represents a point of disagreement among the researchers. One group advocates the idea that automation drives economic growth by increasing productivity and lowering costs and that creates more jobs than it eliminates (Johal et al., 2018).

Dauth, Findeisen, Südekum & Wößner (2017) analyse the impact of industrial robots on employment in German labour markets in the period 1994-2014. Their findings suggest that the robotization has no impact on overall employment in local labour markets that specialized in industries with high robot use. Interestingly, Gregory et al. (2018) find that although automation eliminates jobs, at the same time also creates new jobs and even results in net employment growth. Koch et al., (2019) come to similar conclusions with their analysis of manufacturing firms in Spain (Atkinson, 2019).

Similarly, Adachi et al (2020) show that in Japan, which was a leader in early industry penetration of robots, the penetration of industrial robots had positive impacts on both employment and wages. While the detailed mechanism behind this relationship is not yet entirely clear, expanding production scales by reducing production costs seems to be the key. This implies there is a scope for harmonising human labour with future labour replacement technology, such as artificial intelligence.

Acemoglu and Restrepo (2020) on the contrary show that each additional robot employed reduces employment by seven workers and note that there is little evidence that job gains in other sectors offset these losses. Some studies with a more optimistic view of this issue suggest that workers whose jobs involve tasks that are automated are likely to move to new tasks that are complementary with robots (Johal et al., 2018).

By year 2025, tasks, jobs and skills will be changed due to technological adoption by companies and the consequences of Covid-19 crisis (lockdowns and economic contraction). Thus the automation, together with Covid-19 recession has a "double-disruption" effect for human workers. According to Future of Jobs Survey, by 2025 the time spent on current tasks at work by humans and robots will be the same (World economic forum, 2020).

As more and more low-wage jobs are automated, the prices of the goods and services still produced by low-wage workers also fall in relative terms (if there were no associated cost savings, firms would have no incentive to adopt technologies to increase productivity). These savings reflect in increased spending of consumers across the income range on other goods and services and creation of employment by additional production in industries with low-wage, middle-wage, and high-wage jobs. Hence, the additional demand creates more middle- and higher-wage jobs (Atkinson, 2019).

Demand for the unskilled workers will be further reduced by extensive automation (Daubanes & Yanni, 2019), thus, in the future more emphasis will have to be placed on training programs for less skilled workers. If these workers who represent the most vulnerable group are not trained for new types of employment, this would lead to an increase in wage inequality between the less skilled and high skilled workers. An introduction of robot tax would make robots less affordable compared to routine workers and thus more routine workers with higher wages would probably be hired, thereby reducing income inequality (Thuemell, 2019 in Durán-Cabré, 2019).

Among all expert opinions on the effect of automation on tasks, jobs and industries, there is a common consensus that the future workforce should be prepared with the right skills to seize the higher-skilled and higher paying opportunities offered by automation. The responsibility for the equipping should be on both, government, to provide policies, incentives and programmes to up- and re-skill the workforce and private sector, to increase investment in skills training (IFR, 2017).

In the current setting, where robots are not taxed and human labour is taxed, the system in fact favours the replacement of work with robots. In case of robot tax, a part of the tax return could be used for the compensation or education of workers who were made redundant or for their support. In addition, revenue from robot tax could be distributed in a way that would benefit also those without capital ownership (Vermeulen et al., 2020).

Beside the academic debate and research, there was also **discussion in favour of robot tax among the policy makers and opinion leaders**. One of the leaders in the field of artificial intelligence, Bill Gates claimed that introduction of robot tax would slow down the adoption of technology that replaces human workers and would thus make it more socially accepted. Namely, robot tax could provide resources for the often under-funded services providing care for older people or children. According to Bill Gates, in the long run, human work would largely be replaced by artificial intelligence as it can perform work faster, more accurately and is cost efficient. However, income taxation, currently collected through human labour, cannot be abandoned in order to secure a smooth transition (Huettinger & Boyd, 2019).

Robert Shiller, Nobel laureate in economics known for predicting the 2008 financial crisis, also backed a moderate robot tax as a legitimate element of a policy to confront rising inequality (Kovacev, 2020). He acknowledges that a robot tax may be a more politically acceptable and sustainable approach to tax high-income earners as they usually invest in activities that will eventually replace human labour with robots. A robot tax would also represent a more sophisticated way to tackle the issue of income inequality caused by robot process automation. Alternatively, same results could be achieved by lowering income taxes for low income earners or by subsidizing workforce which would reduce tax costs on human labour and would make it more competitive against robots. Schiller and Yannis Varoufakis both elaborate on the practical problems of defining a "robot tax base, its political acceptability and its sustainability" (Huettinger & Boyd, 2019).

Income inequality and labour displacement deeply impact society which can be seen in social and health problems and conflicts and imbalances in consumption. To solve this issue, most commentators, including Tesla's Elon Musk, propose a fiscally sustainable tax system, able to support and sustain people whose jobs were lost due to automation, with payments from the government. Since "there will be fewer and fewer jobs that a robot cannot do better" Elon Musk claims that introduction of universal basic income will be crucial in the future (McCredie et al., 2019).

European Commission discussed about the regulation of the rise of robots in 2017. The recommendation included an explicit statement in favour of considering a robot tax. The recommendation states that the development of robotics and artificial intelligence raises concerns about the future of employment, social security systems, and the further lag in pension contributions, creating the potential for greater inequality in the distribution of wealth and influence. It was suggested that the risks could be reduced by introducing a tax on the work performed by the robot or a fee for the use and maintenance of the robots, thus enabling the financing of support and retraining for unemployed workers whose jobs have been reduced or eliminated (Kovacev, 2020). The robot tax was rejected due to concerns of reducing innovation.

2.2 Potential negative effects of taxation

According to IFR (2017), productivity improves when robots are used for tasks that they perform with higher efficiency and more consistent quality levels compared to human workers. The study by Graetz and Michaels (2015), which analyse a dataset of 14, mainly manufacturing industries in 17 developed countries over the period 1993-2007, find that robots increase labour and total factor productivity and raise wages. The study suggests that, on average, the use of robots contributed about 0.37 percentage points to annual GDP growth, or more than 10% of total GDP growth over the period, while it contributed about 0.36 percentage points to labour productivity, or about 17% of productivity growth. While the introduction of robots did not have a significant impact on the total number of hours worked, some evidence suggests that robots reduced the number of low-skilled workers employed and, to a lesser extent, the number of medium-skilled workers employed (Michaels & Graetz, 2015).

A recent study of OECD countries find that investment in robots contributed 10% to GDP per capita growth over the period 1993-2016. The study find that a one unit increase in robot density (defined as the number of robots per million hours worked) increases labour productivity by 0.04%. The Boston Consulting Group predicts that productivity will improve by 30% over the next 10 years, driven by the introduction of robots by SMEs as they become more affordable, adaptable and simple to program (IFR, 2017).

The arguments of the opponents to the introduction of robot tax are based on claim that it would affect the companies' capacity for **innovation** and thus reduce incentives for the development and use of robots that complement and relieve human workers (Abbott, 2020; Bendel, 2019).

When discussing robot taxation, tax on robots is sometimes compared to a tax on innovation and, as such, is likely to be a burden on economic growth and prosperity. Since automation and technological progress bring many benefits, imposing limits on innovation is not the best approach to improve tax revenues, workplace stability, and social welfare (Mazur, 2019).

Forecasts suggest that over the next four decades, about 80 % to 90% of economic growth will depend on productivity growth which is driven by innovative capacity, i.e. economy's ability to introduce new products and services with higher value added and more efficient production processes. However, the new dynamics has led to slow diffusion of innovation across and within sectors. This has led to low rates of productivity growth at the aggregate level, with implications for many countries and also for the rise in inequality (World economic forum, 2019).

The success of innovation diffusion depends on the workforce having the right skills to use advanced technologies, and if access to re- and up-skilling were equitably distributed, this would eliminate one source of inequality. However, trade-offs arise at the same time, as technology taxation transfers the tax burden directly from labour to capital, which could hinder the development and diffusion of technologies (World Economic Forum, 2019).

The U.S. Department of Commerce finds that innovation is a critical factor in creating well-paying jobs, as it is the primary driver of real wage increases. A comparison across countries showed that 75% of income inequality can be explained by innovation-driven productivity differentials (Lawson, 2020).

The introduction of a robot tax would increase the cost of robots and thus reduce the incentive for companies to innovate. Although the negative effects of automation should be addressed, it should be done in a way that does not block innovation and penalize technological progress, but instead reaps the benefits of automation (Mazur, 2019).

There were suggestions that by taxing robots, automation would be slowed and thus the economy would gain more time to adjust and provide tax revenue to fund the adjustment. Although this may well be the case, a robot tax presupposes the ability to avoid tax havens where robots could be used tax-free. Beside this it presupposes the ability to clearly separate what is produced by a worker and what is produced by a robot, and the establishment of a notional income paid to a robot as a reference salary. Additionally, a robot tax could hinder the most beneficial applications of robots, where workers and robots complement each other, and those that could drive the creation of new products and new jobs based on digitization (United Nations, 2017).

At this point it is necessary to take into account the fact that the robot tax is a tax on capital, which is not in line with the theory of optimal taxation and could also introduce additional misinterpretations associated with different tax regimes related to robots in individual countries (Vishnevsky & Chekina, 2018).

Arguments against robot tax also point out the question of justice and propose an increase of corporate income tax or capital gains taxes in order to reduce dependence on labour taxes (Abbott, 2020).

As Lawson (2020) explains, the robot tax would perform poorly if measured against Adam Smith's useful maxims for good taxation: proportionality, certainty, convenience, and economy presented in the Wealth of Nations. As Lawson (2020) notes, an ideal tax targets activity that we want to discourage, and the fact that technological progress is not one of them points to the issue of the perspective it takes to approach the challenge of innovation and mass unemployment. Since discouraging the use of robots would limit productivity gains and overall output, everyone would be worse off. Thus, Lawson suggests reaching for higher output and then considering eventual redistribution through more general income increases.

According to Noah Smith, the main argument against robot tax is, as already mentioned, the possibility it would disrupt innovation. Argument builds on ability of new technology to overturn stagnating productivity in rich countries and increase much needed business investment. Taxing new technology could thus only worsen the productivity and investment slowdown. As started by Smith, the problem with Bill Gates' proposal lies in distinction between new technology that complements human workers and new technology that replaces them. In order to address this deficiency, Smith proposes alternative options, for example subsidies for low income workers which would lower the price of human labour or a broader redistribution of capital income from land rents, capital gains and dividends which is currently highly concentrated among the wealthiest. These measures are aimed at decreasing the taxes on human labour and redistributing the income of robots, instead of slowing the innovation (Merler, 2017).

Former US secretary of Treasury and former Chief Economist at the World Bank Larry Summers believes that anything that allows increased production through innovation is desirable. He points out that it is not important to produce more, but more better products and services. He claims that taxing robots is illogical since they are creators of wealth. The tax on robots is thus comparable to neoclassical theories of international trade. For Summers and other scholars, opening up the country to the benefits of international trade is tantamount to providing access to technology that helps transform one good into another. According to this argument, a robot tax could actually direct investment abroad and could harm the domestic economy (Huettinger & Boyd, 2019; Mann, 2019).

In a similar way as in Smith’s argument, Varoufakis rejects the robot tax due to the problem of clear definition of robot and sees a solution in a general tax on the returns of capital goods, which should be transferred to a public trust. Degree of automation would then be reflected in the income stream as well as the dividends distributed to the citizens (Huettinger & Boyd, 2019).

Straubhaar (2017) stated that taxing robots would represent a self-destructive act. He argued that taxing robots would slow down technological advances and worsen workers' competitiveness, as loss of jobs could occur anyway due to foreign competitors employing robots (Mann, 2019). For example, a recent World Bank (2019) report pointed out that a robot tax would reduce productivity.

Daubanes and Yanni (2019) explain that the main argument for introduction of robot tax – compensation for the loss in tax revenue, lacks plausibility. With assumption of stable income shares, increased production due to the use of robots, increases workers’ total payout although routine workers receive lower wages while non-routine workers receive higher wages. In case of progressive taxation, the tax revenue would increase. Thus, the general conclusion they provide is that robot tax is not necessary since productivity gains from the rise of robots should increase rather than reduce tax revenues. One robot tax criticism exposes a problem of generating perception that robots are harmful and that they create negative externalities. Thus, more attention should be placed on alternatives for generating state revenues with less welfare loss (Erdogdu&Karaca, 2018).

Despite its naturally appealing concept, the robot tax proposal sharply contradicts the traditional recommendations of economists regarding the structure of the tax system. Diamond and Mirrlees (1971) describe the optimal tax structure as one where efficiency of production is preserved in priority. That means, in particular, without taxing intermediate goods, such as robots. (Daubanes & Yanni, 2019). Nonetheless, when some of the less realistic assumptions are relaxed, taxing intermediate goods can become optimal again (Daubanes & Yanni, 2019).

Taxing robots might even represent an optimal solution in case when robots partially replace routine workers (Durán-Cabré, 2019).

3 Taxation method, tax base and tax rate

When designing a tax system, two economic factors in particular must be taken into account, the first being the minimization of efficiency losses and the second being the achievement of an acceptable distribution of income (Korinek, 2020).

Most tax systems have been aimed at taxing labour rather than capital since labour taxes are considered as more efficient form of taxation. Capital is indeed more mobile than workers and many countries are in international tax competition, resulting in a strong declining trend in capital tax rates. In most cases, workers must not only compete with increasingly efficient robots, but also with tax policies that promote automation. The latter also allows firms besides the reduction of employer wage taxes, a preferential tax treatment for robots, as companies can demand accelerated depreciation of taxes on capital costs. In addition, workers and consumers are taxed with various forms of indirect taxes (value added tax or retail sales tax) while machines are mostly exempt (Mikesell, 2001 in Huettinger & Boyd, 2019).

The automation process therefore indicates a decreasing trend in total tax revenues that could be altered only by increase in other types of taxation (Huettinger & Boyd, 2019) since automation reduces the overall tax base. In other words, if robots would replace all workers, most of the tax base would disappear. From these point of view changes in tax policy are unavoidable in order to offset the loss of government tax revenue due to automation (Abbott & Bogenschneider, 2018).

An independent expert group appointed by European Commission has presented recommendations on the taxation of the digital economy. Their report places particular emphasis on key features in the further development of the tax framework: no special tax regime for digital companies - general rules should apply to all, steps towards stable and predictable rules, and very restrictive use of tax incentives - to be applied only in case of market failure. The recommendations find consensus among economists, although their implementation is the real challenge. To create conditions for long-term investment, it is crucial to ensure the predictability of rules that go beyond taxation and include both regulation and corruption (Blix, 2015).

As pointed out by Oberson (2019), it is first and foremost necessary to define a clear and workable definition of robots as introduction of a tax on robots brings into questions crucial legal issues. The EU report proposes a definition based on different characteristics, mainly focusing on autonomy, self-learning and adaptation (Daubanes & Yanni, 2019). The international standard ISO 8373:2012, used also by The International Federation of Robotics (IFR), specifies robot as an “actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks". The standard also defines that a robot should include a control system with an interface (Oberson, 2017) Oberson (2019) says the definition should be "neutral" and should include "*robots, bots, and similar types of smart artificially intelligent machines*") with special emphasis on robot autonomy. As he explains, the definition should address the impact of robots on human labour.

3.1 Possible approaches to robot taxation

As Korinek (2020) explains, an important part of the value of robots represents their design and programming, both of which are information goods, while the physical vessel of the robot represents physical capital. He points to a theorem in the economics of optimal taxation that suggests that it is not optimal in the long run to impose taxes on capital, with the intuition that capital is an intermediate good. Since capital is not directly consumed but is used in the production of consumption goods, and if it is taxed, its accumulation is discouraged, leading to a reduced capital stock and discouraging the production of consumption goods. It follows that capital, as an intermediate good, should not be taxed in the long run. Ultimately, however, this could lead to a situation in which everyone is worse off, including the workers whom the taxes are intended to support. As Korinek (2020) concludes, it is therefore crucial to recognize and distinguish between the robot as a "physical vessel" and the robot as a "design and programs that run on it" and to impose a tax on its design and programs, since these represent information goods that generate rents.

Important question arises regarding various possible ways of levying tax on robots. Generally, policy proposals could be divided in two categories. The first supports direct taxation of companies that benefit from automation, while the second proposes indirect taxation, where companies are not directly taxed, in order to avoid a possible stagnation of innovation. Such stagnation could be more evident in healthcare and transportation sectors were automation is crucial for efficiency and quality of services (McCredie et al., 2019).

Various possibilities of direct robot taxation should be examined. Oberson (2017) proposes an income tax on *robot's salary*. Such tax would be imposed on robot's hypothetical salary determined by assuming the equivalent work was done by a human. Justification for such tax would be based on fact that robots replace human workers without compensation for the latter (Oberson, 2019). In case that robot tax is levied on income related to activities of the robot, the issue of "double taxation" of income could arise. First, the tax would be levied at the level of robot which would be on robot's imputed salary or income from its use and second, at the level of corporation (Oberson, 2017).

Alternatively, such tax could take form of a simple fixed lump-sum amount that would recognize "tax liability" related to robots. Initially, the capacity to pay the tax would be attributed to the employer or owner of the robots, but as the technology evolves, the robot's ability to pay could be recognized (Oberson, 2017).

A more traditional solution could simply represent an introduction of an objective tax on robots, similar to tax on vehicles. Some types of these robot taxes have already been introduced or planned on drones or self-driving cars in some US states. Since robot tax is a feature of the machine tax, there is also option to apply VAT to robot activities. Robotics and automation are currently subject to VAT due to their contribution to the added value of the production distribution process (Oberson, 2017).

Another proposal represents a tax based on a worker to profit ratio, which would affect firms with high profits but a small workforce (Oberson, 2017; Walker, 2017 in McCredie et al., 2019). Other proposals place attention to performance point of view and suggest a performance-related levy which would be based on performance (e.g. computing power) or capacity of the robot (Jones, 2018 in McCredie et al., 2019).

Vishnevsky & Chekina (2018) propose a tax which would not be imposed on robot but on the use of robots. By looking at example from environmental protection, D'Orlando (2018) presents an approach based on tradable permits, similar to pollution quotas. This approach includes quotas on human employment tradable between other firms or countries.

Recently proposed suggestions regarding indirect robot taxation propose a tax neutral system between robots and human workers. In this direction, some academics support an "*automation tax*" which would be based on the ratio of a company's total revenues and total number of employees. Abbott & Bogenschneider (2018) propose a creation of an "automation tax" by combining several measures. These include elimination of corporate tax deductions related to automated workers, introduction of tax preferences associated to human workers, corporate self-employment tax and an increase in the corporate tax rate. The goal of combining these measures is to achieve tax neutrality by creating a system where alternatives are taxed equally and thus decisions should no longer be made based on tax reasons.

Paul-Choudhury (2017) mentions a tax system where tax incentives for the retraining and upskilling displaced workers would be introduced. Such system with a bias towards human workers should also consider subsidized wages or reduced payroll taxes for low-income workers (McCredie et al., 2019). Other suggestions include adoption of certain quota on the number of human workers that should be maintained in specific business. Possible intervention policy to alleviate the problem of redundant human labour could be the introduction of a universal basic income or enhancing innovativeness in order to encourage the development of new sectors while also increasing labour mobility (McCredie et al., 2019).

In this context McCredie et al. (2019) suggest three alternate models of taxation. These are Pigouvian tax, tax on economic rents and an appreciation tax. Pigouvian taxes are aimed at offsetting the externalities (e.g. carbon taxes, tobacco and alcohol). Following this logic, social costs of the externalities, resulted from automation, should be internalized by the enterprise.

Second, tax on economic rents represents a tax on surplus due to automation while the third, appreciation tax is established on the basis of taxing capital gains and as proposed by McCredie et al. (2019) should be accrued annually rather on realization of the capital item.

The last but not least remains the question who actually pays the taxes? In US, the Internal Revenue Code defines a taxpayer as “an individual, a trust, estate, partnership, association, company or corporation”. Currently, a robot cannot be defined by any of these terms, thus a tax on robots represents a tax on humans or entities “who own, use, or benefit from the use of robots”. However, it is more complex when it comes to the question which group should pay the tax-should the tax be imposed on the robot’s manufacturers, business who purchases and uses them or the consumers of goods or services provided by robots (Kovacev, 2020). The issue becomes even more complex in case of proposal to tax robots equivalently compared to lost taxes of displaced workers. Though, the example doesn’t include a situation if a business uses robots, but doesn’t fire any employees or fires low-skilled but hires new high-skilled employees. In the case of robot tax based on income generated by robots, it would be hard to exclude which income is generated by robots and which is not. So, this would be, as Kovacev, 2020 states, more a case-by-case analysis.

Berberov and Milogolov (2020) suggest that the Russian tax system could be an example of a positive version of the robot tax, aimed at incentivizing reinvestment of profits from highly digitized firms. Introducing the limit on deducting expenses for the use of foreign technologies from taxable profits to an appropriate level could be a measure to prevent the shifting of profits through royalties to low-tax countries.

3.2 The optimal taxation of robots

In addition to the problem of what can be defined as a robot that replaces labour and what is the appropriate method for taxation, several issues can be related also to the determination of the appropriate tax rate. Based on a quantitative model of automation Guerreiro, Rebelo and Teles (2020) find for current US tax system a correlation between the decrease in automation costs and a substantial increase in income inequality as well as a considerable decline in the welfare of workers in routine occupations. In their model, robots are complements to non-routine workers and substitutes for routine workers. If the different flat taxes are imposed on each type of worker, technological progress is always welfare enhancing because its gains can be redistributed. In practise, however, discriminatory flat taxes cannot be imposed, either due to the lack of information about worker types or due to political and cultural pressure on the tax system.

Guerreiro et al. (2020a) consider two settings in which occupational choice is exogenous and endogenous. In the first setting, where some workers are born for non-routine jobs and others for routine jobs, it is optimal to tax robots if the goal is to redistribute income towards routine workers. In the second setting, the optimal tax system would require balancing two goals. The first objective is to provide incentives for younger generations to invest in skills, and the second is to redistribute income in favour of routine workers as their wages fall when robots become cheaper. Thus, as proposed by the authors, robot taxation reduces the wage premium for non-routine workers and allows income to be redistributed in favour of routine workers (Guerreiro et al., 2020a).

They suggest that in order to tax robots in an optimal way, they should be taxed while the current generations of routine workers (who cannot perform non-routine tasks) represent active labour force. The optimal tax rates for robots implied by the model are reasonable: 7% in the first decade, 3% in the second decade, and 1% in the third decade. As with their retirement, optimal robot taxes would be zero.

Thuemmel (2018) studies optimal taxation of robots in relation to labour income. In his model, robots substitute routine labour and complement non-routine labour. He provides optimal policy for two scenarios. In one scenario individuals are able to switch occupation due to robot tax and in the other scenario they are not able to switch occupation. With model calibrated for US economy he finds that in case when occupational switching is not possible, the optimal tax on the stock of robots is 1.8 % and the welfare gain of robot tax introduction is approximately 21 $ per person annually. In case of occupational switching, robot tax equals 0.86 % and its effect on welfare is reduced to approximately 9 $ per person annually. In both cases, if robots can be taxed, optimal marginal income taxes are higher in low to medium incomes and lower at high incomes. He also studies the impact of a drop in price of robots for these two scenarios and finds that in both cases, wage inequality eventually increases with the fall of the average wage of routine workers, while non-routine workers observe wage gains.

Costinot in Werning (2018) provide a general theory of optimal technology regulation where they present three new optimal tax formulas. Though all three with slightly different statistical background, they all point to the impact on wage distribution. By observing the magnitude of optimal taxes on robots and trade they find that efficient robot taxes range from 1 % to 3.7 %.

Effects of robot tax in general were recently analyzed by Gasteiger and Prettner (2020) who present its potential to increase per capita capital and output, wages and welfare at the steady state. However, the results should be observed with caution in case innovation and automation represent endogenous variables. In such situation robot tax could decrease technological progress and reduce economic growth due to reduced incentives to invest in new technologies. Finally robot tax could reduce the future income compared to the situation before the introduction of robot tax.

While most of the existing economic models assume a clear distinction between routine and non-routine jobs, in reality most jobs combine a set of tasks. Some of these tasks can be automated with little effort while others require cognitive and social intelligence. Introducing robot tax would thus be based on assesment of the degree to which automation could be substituted and complemented (Daubanes & Yanni, 2019).

In their discussion Acemoglu, Manera, and Restrepo (2020) mention that one option would be to impose "*automation taxes*" that would at the same time correct some of the distortions created by the asymmetric tax code and would allow firms to decide which automation technologies to invest in. Their "automation tax" differs from taxes on robots since it is not a uniform tax imposed on all automation technologies, but is applied to technologies that automate tasks above a certain threshold (tasks where humans still have a significant comparative advantage) (Acemoglu et al., 2020a). The rationale behind the "automation tax" is not to tax all forms of capital automation, but to concentrate on automation technologies that are used for marginal tasks where they do not yield large productivity gains. More specifically, the "automation tax" should not be applied to cases where automation increases productivity and creates new jobs. Though, the identification of these "marginal" cases would represent a challenge for the tax code (Acemoglu et al., 2020b; Acemoglu et al., 2020a).

Overall, the taxation of robots represents an issue that extends beyond national borders and should be properly addressed by tax authorities on international level. Namely, the introduction of robot tax requires a coordinated move across countries otherwise countries could face a risk of tax revenue loss due to tax competition and could lead that companies simply to relocate robots to areas without a robot tax (Durán-Cabré (2019), Gasteiger & Prettner (2020)).

4 Conclusions

This paper reviews the literature on the question of whether and how robots that replace routine jobs should be taxed. While earlier structural changes were slow and allowed sufficient time for adaptation, the current processes of automation and robotization are faster. However, although this rapid pace of automation may destroy many jobs and lead to a dramatic increase in income inequality, there is no consensus among economists on whether public intervention is needed. One strand of economists argue that taxing robots would be a self-defeating act. Taxing robots would spur innovation and slow down technological progress, thus worsening workers' competitiveness, since job losses due to the use of robots by foreign competitors could occur anyway.

Another strand of economists that seems to be gaining ground, however, argues for public intervention. It is thought that the risks posed by the replacement of routine jobs and rising inequality could be reduced by the introduction of some kind of tax on the work performed by robots. The first reason is that by taxing robots, governments will be able to generate tax revenue to offset the declining revenue from taxing labor when human labor is displaced by machines. The second reason for taxing robots is to prevent or limit income and wealth inequality that arises from potentially increased inequality among the types of workers affected by automation and from the transfer of income from workers to owners of capital.

Despite the consensus among this latter group of economists on the need for some sort of tax on robots, however, there is as yet no agreement on the precise framework of the tax policy to be introduced. There is no agreement on either the tax base or the tax rate. In general, policy proposals fall into two categories. The first supports direct taxation of firms that benefit from automation, while the second proposes indirect taxation, where firms are not directly taxed to avoid possible stagnation of innovation. As for the first, the simplest idea is to introduce an objective tax on robots, similar to the tax on vehicles. But while such a tax would discourage innovation, companies could also resort to avoiding the tax burden by moving automated production abroad to countries with more favorable regulations.

Under the second proposal, the tax would be levied not on robots but on the use of robots, in such a way that firms would pay for the negative externalities of using robots instead of humans. This is similar to a tax on economic rents, i.e. a tax on the surplus due to automation. Therefore, a robot tax would be levied similarly to a VAT tax on robot activities. Guerreiro et al. (2020a) consider a regressive tax rate on robots with a tax rate that decreases with the age of the robots. The optimal tax rates on robots implied by their model are reasonable: 7% in the first decade, 3% in the second decade, and 1% in the third decade. As for their retirement, the optimal robot tax would be zero.

In any case, the taxation of robots is an issue that transcends national borders and should be properly addressed by tax authorities at the international level. Indeed, the introduction of a robot tax requires a coordinated approach between countries, otherwise there is a risk that countries will lose tax revenue due to tax competition, which could lead to companies simply relocating their robots to areas without a robot tax.

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