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Second Year Policy Analysis

Does Brazil Need to Prepare for the Age of Artificial Intelligence?

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Written in fulfillment of the requirements for the degree of Master in Public Administration in International Development, John F. Kennedy School of Government, Harvard University.

March 18, 2019

Image credit: João Abreu

Acknowledgements

We are deeply thankful to our advisor, Prof. Isabel Guerrero Pulgar, for the very insightful guidance that came invaluable as we were navigating the sea of aspects in which emerging technologies impact national development trajectory.

We are extremely grateful to our seminar leader Prof. Carmen Reinhart for the incredible generosity of attention and depth of advice she gave us at every step of the process.

The data analysis part of this work would not be possible without the support and advice of Prof. Frank Neffke and especially Prof. Ljubica Nedelkoska. Beyond the Harvard Kennedy School faculty, we would like to thank Synthia Santana of IBGE and Prof. Gustavo Gonzaga. This work would be less complete if it wasn't for Prof. Pedro Albuquerque and his co-authors' generosity in sharing their own work with us in advance of publication, and discussing our results.

We are grateful to Prof. Arvind Subramanian for being generous with his time and brainstorming with us with excitement and enthusiasm. We thank Siddhartha Raja, the World Bank's Senior Specialist for Technology & Jobs, for sharing his rich insights on the role of automation in developing countries. Our understanding benefited greatly from the conversations we had during the field trip to Brazil, especially those with Vinicius Botelho, Secretary of Social and Productive Inclusion, Tulio A. Cravo, IDB's Labor Market specialist, Alessandro Passos (Berê), and Hugo Nunes of the Ministry of Citizenship. We thank Robert Kirkpatrick, Director of UN Global Pulse, for sharing his valuable perspective and encouraging the very inception of this work.

We would like to extend a special gratitude to the fantastic team of the AI Initiative at The Future Society think-and-do-tank: Yolanda Lannquist, Nicolas Miailhe, Buse Cetin, Nicolas Moës, Arohi Jain and Isabela Isa. The opportunity to have frequent in-depth discussions of our work, receive extraordinary generous amount of feedback, exchange ideas and learn from the team's vast expertise in AI policy greatly enriched our product.

We thank MPA/IDs' intellectual parents—Prof. Dani Rodrik and Prof. Lant Pritchett; their work and thought leadership inspired not only this project, but many of our future pursuits.

We are forever grateful to our parents—Vivian de Cerqueira Leite, Sérgio Moraes Abreu, Marina Klinova and Alexander Klinov—for their unbounded unconditional love, the best launchpad we could ever wish for.

Not listed here, but treasured in our hearts, are names of mentors, colleagues and friends who have been an unwavering source of support and encouragement on our graduate school journey.

All remaining errors are our own.

Executive Summary

We have entered an era of rapid advancements in the intelligent automation technologies, which could have profound implications for the viability of existing social and economic structures around the globe. Yet, discussion of policy responses that can ensure an equitable distribution of benefits from the upcoming technological changes often focuses implicitly or explicitly on developed economies. The present study discusses economic risks specific to developing countries that might arise from the progress of intelligent automation, and analyzes the relevance of commonly suggested solutions in the context of Brazil.

We apply Frey and Osborne (2017) estimation of automatability of U.S. occupations to obtain a proxy of likelihoods of automation for 373 out of 433 occupations from Brazil's classification database (COD), corresponding to 94% of the Brazilian labor force. Our analysis suggests that 44.5M people, or 53% of Brazil's formal and informal workforce, are employed in occupations with 70% or higher probability of being automated. We find that the likelihood of automation is highest for people on the lower end on income distribution, people with less than 12 years of education (high school level or below), and youth under the age of 24.

The present work discusses the applicability of Universal Basic Income and Life-Long Training Accounts in the context of Brazil as potential policies for making workers more resilient in the face of possible structural changes. We argue that neither of these popular proposals can be scaled in Brazil at present without imposing substantial risks on debt sustainability. Instead, we suggest to adapt the current vocational training programs to ensure their relevance in the context of rapid advances in intelligent automation domestically or internationally. We propose to use state-specific distribution of occupations by automation susceptibility for defining the composition of vocational training courses to be offered in each state, anticipating student inflows and their skill make-up. We also suggest to train career guidance agencies to identify the shortest re-skilling path from individual's existing occupation to a less-prone-to-automation occupation using skill proximity trees.

Table of Contents

1. Policy Questions of Interest and Hypothetical Client

Policy Questions of Interest

This report will investigate how increasing advances in intelligent automation technologies will impact the growth prospects of developing economies, focusing the analysis on the case of Brazil.

We seek to address the following policy questions:

- what risks, if any, does intelligent automation pose for developing economies?
- given the traditionally protectionist response of Brazil to the trade liberalization-induced shocks to comparative advantage, what risks would its economy be subjected to if Brazil chose to respond to the advancement in intelligent automation in a similar fashion— with digital protectionism measures?
- which administratively feasible and fiscally sustainable steps can the government of Brazil take in the short term to address those risks without adversely impacting the country's ability to benefit from potential gains brought by intelligent automation?

Hypothetical Client

The assumed client for this SYPA is the Minister of the Economy of Brazil. The newly formed Ministry of the Economy covers the scope previously under discretion of the following ministries: Finance, Planning, Industry, Foreign Trade and Services.

What is Intelligent Automation?

Before proceeding with the discussion of economic development implications, it is necessary to clarify what we mean by "intelligent automation" and "transformative AI"— terms which this paper will use interchangeably.

Automation of labor is not a new phenomenon, and has been underway since at least the industrial revolution (Aghion et al., 2017). Artificial Intelligence technologies greatly expand the scope of tasks that can be automated. As noted by Brynjolfsson et al. (2018), while previous waves of automation mainly affected tasks that could be broken down into steps or codified with explicit rules, the recent advances in Machine Learning (ML) enable the automation of tasks which would be impossible or prohibitively costly for humans to codify explicitly. Thus, ML allows to make entire domains of previously unattainable for machines tasks automatable. For example, a deep reinforcement learning-enabled technology can convert conventional warehouse robot arms from machines suitable only for handling very precisely placed and shaped identical objects to machines that can identify any object in front of them, test how it behaves in response to various types of physical interaction and work out how to handle this and similar objects (Knight 2018).

Instead of displacing one task at a time with each new type of machine, intelligent automation can render whole sets of similar skills and abilities redundant (Diodato, Neffke, Nedelkoska 2018), and has a potential for achieving high degrees of task substitution. While the arrival of Artificial General Intelligence which could allow for complete automation remains highly uncertain, even a linear progression of the existing Artificial Narrow Intelligence technologies, which allow machines to perform a narrow set of tasks at a human or above-human levels, is sufficient to accumulate changes that can have transformative impact on many, if not most, production processes (Brynjolfsson et al. 2018), hence the label "transformative AI".

The present paper does not assume an arrival of Artificial General Intelligence in the short or medium term; it proceeds by discussing intelligent automation as a dramatically expanded continuation of automation we have been seeing for much of the 20th century, brought to a new level by the advancements in Machine Learning technologies, data and computing accessibility. These advancements allow for the automation of not only routine and highly repetitive tasks, but also tasks that cannot be easily broken down into steps (i.e. driving, image recognition), and even those that require high degrees of creativity (i.e. translation, playlist curation).

2. Does Intelligent Automation pose risks for developing economies?

There is a growing recognition of Artificial Intelligence as the newest general purpose technology (GPT)—a technology that “becomes pervasive, improves overtime, and generates complementary innovation” (Brynjolfsson et al. 2018). It is thus tempting to expect the economic transition period following the arrival of commercial-grade intelligence automation to be not too dissimilar from the transitions that accompanied the introduction of previous GPTs (steam engine, electricity, railroad, etc.) Those generated multiple adjustment difficulties for entire segments of population in the short term, but in the long term led to massive economic gains, and the “lifting of all boats.”

While readily subscribing to the enthusiasm about the long-term potential for prosperity and abundance that AI can unlock for the humankind, we consider it important to note that the economic difficulties brought by the previous GPT- or trade-induced transitions did not auto-resolve themselves, those that were addressed were addressed with considerable policy efforts. This paper will therefore focus on discussing the welfare risks associated with the transformation of the global economy brought about by intelligent automation, and the factors that can make the transition period lengthier, more disruptive or lead to long-term structural disadvantages for particular countries. Identifying those factors is critical for formulating policy options that can help minimize potential disruptions.

It is still early days for the literature on the ways in which the practice of economic development needs to evolve to remain fit-for-purpose in an AI-driven global economy; the existing thinking on the challenges intelligent automation might pose for development fall under the following main topics:

- Inherent bias of AI-driven technological advancement which affects productivity of population segments differently depending on their initial skill level;
- Diminishing substitutability of low-skilled labor for technology and high-skilled labor and the resulting transformation of global value chains;

- Potentiality of a stable entrenchment of the divide between countries leading AI advances and the rest of the world, due to pervasiveness of the "data current account imbalance" (term coined by Weber 2017) and the winner take all dynamics.

Skill-biased Technological Change

As cited by Brynjolfsson and McAfee (2014), Solow's (1957) theoretical model describes technological change as an equal multiplier to everyone's productivity, but multiple recent studies have documented that technological change has been differentially impacting the U.S. labor force at least in the last 30-40 years. New technologies have been complimenting skilled labor, boosting its productivity and the demand for it, while increasingly substituting for unskilled labor, depressing the demand for it and driving down respective wages, earning the name "skill-biased technological change" for the phenomenon. AI-enabled technologies are unlikely to decrease the skill bias of the latest form of technological change, which has already served a major force behind the widely discussed "hollowing out" of middle-wage paying jobs across many advanced economies of Europe and North America (Autor 2015).

If one accepts that a large national economy can serve as an approximate model of the world economy, it is easy to see the risk of the above trend expanding globally, with technological advancement advantaging first and foremost countries well endowed in skills and capital, while driving down the demand for the low-skilled labor around the globe. The situation for developing countries, many of which have been struggling to improve educational outcomes for decades, is further complicated by the difficulties they have with retaining their best talent. In the words of Nobel laureate Jean Tirole, "Countries not taking part in this global competition for talent will not be able to redistribute wealth to the poor, because the poor will be all that they have." (Tirole 2017.)

Transformation of Global Manufacturing Value Chains

It is being increasingly understood that skill-biased technological change has the potential to weaken the very basis of developing countries' comparative advantage, which has served as an important driver of growth for many of them thus far—competitive levels of wages for low-skilled labor. 59% of 313 global businesses surveyed for the World Economic Forum's "The Future of Jobs" report (2018) expect to have significantly changed the composition of their value chains by 2022, with 74% of respondents basing their job location decisions on availability of skilled labor as a key factor that outweighs labor costs in importance. 50% of companies surveyed expect to reduce the size of the workforce by 2022 due to automation, 28% expect to expand it in the same timeframe.

As cited in WEF (2018), Bain's "Labor 2030: the collision of demographics, automation and inequality" report points out that in 2013, manufacturing value-added per dollar of labour cost was 15% higher in Mexico than in the United States, which is a drop from Mexico's value-added per dollar being twice higher than in the U.S. in 1997. As the WEF report notes, if the trend of re-shoring of work tasks continues over the next five years, "it is not inconceivable that shifting comparative advantage in labour costs will affect the industrial structure of [developing] economies."

Intelligent automation is likely to transform production of goods and services in a way that will make it a lot harder to compensate for lack of advanced machinery, algorithms and capabilities by adding more unskilled labor into the mix, effectively retiring the growth driving contribution unskilled labor has had in the industrializing world thus far. As cited by Rodrik (2018), Raval (2018) finds that the degree of substitutability of unskilled labor for other factors of production is already much lower in electrical machinery than in garments industry; Oberfield and Raval (2014) point out that it is also much lower in advanced economies like the U.S. than in emerging markets, with India currently having the highest degree of substitutability.

Rodrik (2018) models how production costs of firms change with the movements in the amount of productivity-boosting technological change and the degree of substitutability of unskilled labor for other factors of production. The paper points out that the share of developing country firms that remain viable shrinks as technological productivity multiplier increases and the degree of substitutability falls; moreover, these effects reinforce each other: a unit reduction in the degree of substitutability implies a much bigger competitive penalty for developing countries when the productivity multiplier from technological change a is higher. In other words, the higher is the degree of technological advancement, the bigger is the decrease in wages that is necessary to restore the competitiveness of a developing country after a technologically-induced productivity shock.

In "Straight Talk on Trade" (2017), Rodrik mentions the reduced substitutability of low-skilled labor for capital and high-skilled talent as one of the major factors driving premature deindustrialization, a phenomenon observed in many developing countries (including Brazil), where the share of manufacturing in the output and employment peaked at much lower levels of income than what was experienced by developed markets. Industrialization played a critical role in development because it enabled a "developing countries-friendly" growth model: even if a country lacked in such means of production as capital or high-skilled labor, it could have low-skilled labor substitute for those to a large degree, and still achieve significant development progress. With manufacturing-led growth running out of room in many developing countries prematurely, the question of whether a growth model that replaces it will be developing-countries friendly gains urgency.

The Nature and Growth Implications of Data Value Chains

Another aspect differentiating AI- and data-enabled technological change from previous transformations brought by then-new GPTs is that, unlike manufacturing value chains, "data value chains" do not come with a built-in development ladder (Weber 2017). If, as a part of a manufacturing value chain, a country is exporting a relatively simple production input and importing the final high value-added product, it can progressively learn the more complex production techniques and eventually accumulate enough capability and know-how for producing higher value-added products domestically. An example could be going from making basic automotive parts to producing full automobiles. But if a country is "exporting" raw data of its residents and importing a high value-added AI-powered product or service that uses that data, the way it can leverage this value chain relationship to "learn" how to build a domestic AI-driven industry is a lot less clear.

As remarked by Weber (2017), a country that is systematically running such "data current account" deficit is at risk of finding itself at a persistent development disadvantage, which might eventually shut it out of the production side of the AI and data economy.

Since most machine learning algorithms improve with more and better data fed into them, a first-mover advantage can prove "sticky" for AI-enabled services and lead to deeply entrenched monopolies and winner-takes-all dynamics. In addition, as Valletti (2019) points out, a player in a data economy with significant market power is more likely to get away with requesting broader permissions on the uses of personal data through terms of service or privacy policy statements, which users usually accept if doing otherwise would prevent them from accessing the service. Broader data usage permissions can be a competitive advantage and serve to further strengthen the player's market position.

Given the above considerations, and the speed with which technological advancement is changing the realities of the global economy, it becomes important for the policymakers in developing countries to devise measures for retaining their countries' and workers' competitiveness in the AI-driven world. Those measures need to be feasible for the countries to implement given their levels of income, total debt, educational outcomes and existing room for fiscal maneuvering. The challenge for developing countries is compounded by their comparative advantage in standard manufacturing likely diminishing in the face of increasing adoption of AI-enabled technologies by advanced economies (Rodrik 2018). The practice of international development needs to evolve rapidly to be able to effectively address these challenges and remain fit-for-purpose in the world transformed by AI.

This paper will focus on the steps the government of Brazil can feasibly take in the immediate term in order to boost the resilience of the Brazilian labor force in the face of potential shocks to the global economy brought by the advancement in intelligent automation. Such shocks are likely to disproportionately affect the people in lower-wage jobs and with lowest levels of educational attainment—an aspect that needs to be central in the policy design. We will also assess the potential and downsides of digital protectionist measures, which are likely to surface as suggested responses to intelligent automation-induced shocks in a country that has maintained one of the lowest levels of trade integration in the world.

The remainder of this paper is structured as follows: Section 3 provides a high-level overview of the current state of Brazil's economy, including its macroeconomic situation, educational outcomes, labor market conditions and digital readiness; Section 4 presents an assessment of susceptibility to automation of Brazil's occupations; Sections 5 and 6 discuss a range of policy alternatives that could be considered and their feasibility in the present Brazilian context; Section 6 provides the final policy recommendation, and Section 7 concludes with an overview of further research directions.

3. Current State of Brazil's Economy

Brazil's Economic Context: a High-level Overview

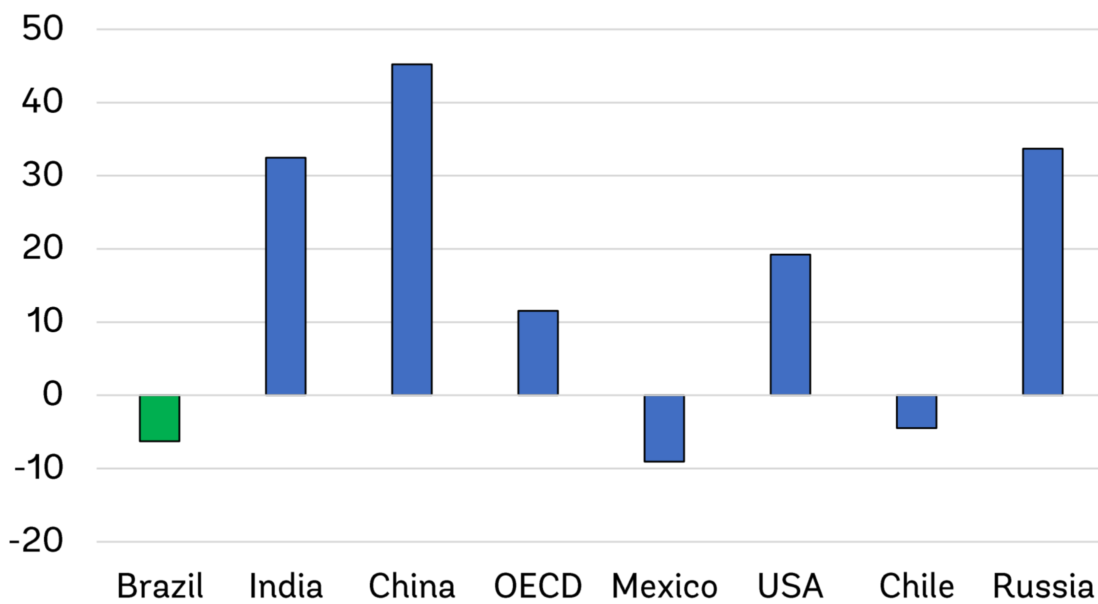
Brazilian GDP grew in 2018 at about 1.4% (results after three quarters), with inflation under 4% and average unemployment rate of 11.9% across the country; Northeast experiencing the highest unemployment of 14.4% and South experiencing the lowest level of unemployment of 7.9% (Banco Central Do Brasil, 2019). There has not been any convergence in per-capita incomes between Brazil and the United States in the last 30 years, with Brazil's TFP (Total Factor Productivity) falling negative in the last decades (World Bank 2018), as displayed in the chart 3.1 below.

The World Bank (2018) lists the following reasons for such performance:

- on the level of firms, comparatively poor managerial quality and underinvestment in innovation;
- Poor business environment (Brazil is 125th in the Doing Business rating);
- Comparatively high tariffs and non-tariff barriers, that kept trade at 25% of Brazil's GDP on average between 2010 and 2017 - lowest ratio in the world;

- High distortions from federal policies (4.5% of GDP), many of which do not address market failures but weaken competition.

Chart 3.1. Total Factor Productivity Growth during 1995-2014



Source: World Bank (2018); World Bank calculations using Penn World Tables (2016).

From the macroeconomic point of view, Brazil is still recovering from the deep recession of 2016, with its debt still mounting under the pressure of non-flexible fiscal spends and one of the most generous pension systems in the world. Current level of debt is 84% of GDP, and it is projected to peak at above 90% of GDP in 2023. The growth is projected to pick up modestly in 2019 and reach 2.5% of GDP (IMF 2018). Rigidity of public spending and budget ear-marking practices make over 90% of federal spending mandatory, making it difficult to implement the 5% per year fiscal adjustment that Constitutional Amendment 95/2016 mandated through 2024 (World Bank 2018). World Bank (2018) calls restoring fiscal sustainability "the most pressing economic challenge for Brazil." Newly appointed government of Jair Bolsonaro is widely expected to pass a pension reform in 2019 to address the worries of unsustainability of the fiscal burden.

Brazil's Labor Markets Programs and Policies Overview

In a comprehensive diagnostics of Brazil's primary economic development challenges produced in the summer of 2018, the World Bank's technical team highlights a set of features of the labor markets policy in Brazil (World Bank, 2018). This section presents a selection of those features especially relevant for the discussion of Brazil's capacity to adapt to the world of AI-driven global economy.

- Labor market programs spent in Brazil is above OECD average, 2.8% of GDP, where 1.1% of GDP is financed by the Federal budget, and the rest through mandatory labor programs paid for by employers.
- The majority (96%) of labor market programs budget is spent on income support, with upskilling, intermediation and job search assistance remaining largely neglected due to systematic underfunding and lack of capacity in the local offices of Sistema Nacional de Emprego (SINE).
- Unemployment income support is uncoordinated, resulting in a significant overlap between programs (FGTS, Seguro Desemprego).
- Replacement level of previous wages is comparatively high, while the duration of unemployment income support is short, putting at a disadvantage the most vulnerable and low-skilled populations who might need longer to find new work.
- Unemployment income support targets those who recently lost their formal jobs, which results in exclusion of most in the bottom 40%, unemployed youth and long-term unemployed.
- Wage subsidies for working poor (Salario Familia and Abono Salarial) do not create incentives for hiring the most vulnerable populations - unemployed youth, first-time job entrants, and long-term unemployed.
- According to OECD (2018), the youth unemployment rate in Brazil in 2016 was 25.9% (OECD average is 13%).

Assessing Brazil’s Preparedness to Transition to the AI Economy

To benchmark Brazil’s readiness to transition to an AI-driven economy, we relied primarily on two indexes (WEF 2018 and EIU 2018), as well as macroeconomic data for Brazil (IMF 2018).

The Automation Readiness Index developed by the Economist Intelligence Unit compares 25 countries based on 52 indicators that assess the favorability of their innovation environment for the development and adoption of intelligence technologies, as well as the fit of educational and labor market policies to the particular demands of the AI-driven world economy (see Appendix 4).

Brazil’s innovation environment is rated last out of 25 countries assessed (G20 plus UAE, Estonia, Colombia, Vietnam and Singapore) based on such indicators as R&D investment in robotics, AI and automation, regulatory framework for innovation and automation adoption in existing industries, depth of international partnerships and other knowledge transfer schemes, startup support programs, connectivity infrastructure support, cluster development programmes, data protection and cybersecurity, and data literacy levels.

In terms of educational policy readiness, Brazil is rated 17th out of 25, based on the levels of development of early education programs, lifelong learning programs and technology education programs, 21st century skills strategies, use of AI in education, career guidance programs, and the depth of social dialogue with educators and industry about the ways education system needs to evolve to fulfill the needs of the AI -driven economy.

Lasty, Brazil’s labor market policies were rated 13th out of 25 based on the level of advancement of the programs for the development of future jobs-relevant skills, government-led research on automation and its impact on labor markets and dissemination of that knowledge, and collaboration between public and private sectors on workforce transition programs.

Brazil’s overall ranking in the Automation readiness Index is 19th out of 25, with its score being half that of the Index’s leader, South Korea.

For its 2018 Future of Jobs Report, the World Economic Forum surveyed 313 global companies from 12 industry clusters about their expectations about the changes to their own business that will occur between 2018 and 2022. Based on the survey responses of companies operating in Brazil, it is estimated that 53% of the country's workforce will be in need of re-skilling, with 41% requiring a reskilling training of longer than 1 month, and 9% — of longer than 1 year. 92% of surveyed companies with operations in Brazil expect to have adopted big data analytics by 2022, and 79% - machine learning as a part of their growth strategy.

An evaluation of Brazilian educational outcomes conducted by the Programme for International Student Assessment (PISA) in 2015, showed that Brazilian school students perform significantly below the OECD average in both science, math and reading (401 and 407 points respectively in science and math vs 493 OECD average; 377 points in reading compared to 490 OECD average). Nearly 60% of students do not attain basic proficiency in science (nearly 3X the OECD average), and 8% of students are not required to attend any science lessons. 70% of Brazilian students fail to achieve the most basic level of proficiency in mathematics (vs 25% OECD average). There has been a noticeable widening of achievement gaps between the top performing 10% of students and weakest performing 10% in both science, math and reading. As the 2015 PISA Country Note for Brazil states, "[t]he widening of the achievement gap may underline the significant challenges faced by Brazil in integrating the weakest students in a fast-changing society, where opportunities are increasingly shaped by knowledge, skills, and technology."

More detailed information about the Brazilian labor market and its susceptibility to automation, to the best of our knowledge, does not exist yet. The next section attempts to fill this gap and provide data to inform potential public policies, discussed in Section 6.

4. Analysis of Susceptibility to Automation of Brazil's Occupations

Are Jobs Really at Risk of Automation? Existing Literature Overview

Frey and Osborne (2017) seminal paper reached the headlines of newspapers around the world. In particular, the authors concluded that 47% of jobs in the United States "*could be automated*", raising concern among the public.

This work builds on their work, and in particular on their assessment on the risk of automation for each of the U.S. occupations, obtained by combining expert input and extrapolation based on skills required for each occupation (details in Appendix 3). Their ingenious and pioneer approach made the paper widely cited in the growing AI and automation literature. Box 1 explains what this approach *cannot* inform.

BOX 1: WHAT DO WE REALLY MEAN BY "RISK OF AUTOMATION"?

The fear of technological displacement goes back at least to Keynes (1930). However, it is important to distinguish between i) having the technological ability to execute a given set of activities without humans, and ii) developing a technological solution that can actually do it *cheaper* than humans. Only the latter can have significant consequences for the economy and the labor market.

This point is especially important when results are transposed across countries, as attempted in the present work (from the U.S. to Brazil). In developing countries like Brazil the costs of labor are substantially lower than in the developed world, even for equivalent workers (Clemens et. al, 2016). The same can be said for Latin America and the Caribbean more generally (Bosch and Ripani, 2018). Therefore, just because society has developed the technology needed to automate a given occupation, it does not mean that it will reach economic viability anytime soon – in the United States and even more so in Brazil and other countries where human labor is comparatively cheaper.

We make no attempt, here, to assess economic viability of automation—we limit our analysis to the technical dimension of new technologies, borrowing from Frey and Osborne. When we say "risk of automation" in this paper, we are talking about the likelihood that a given occupation can, from a technological point of view, be automated in the near future. We are not suggesting anything about *when* that will be commercially feasible, in Brazil or elsewhere.

Nevertheless, the likelihood that we will have the technology to automate a given occupation in the near future does provide a useful proxy for the relevance and bargaining power of workers in that occupation. The existence of the technology to automate is not sufficient but it is necessary to achieve economic viability of automation and to have real implications in the labor market. Additionally, such technology can arguably impose a ceiling to real wages and therefore reduce their relative value over time, when compared to occupations that under no circumstances could be automated away.

For those reasons, it matters to understand which occupations, in a given economy, are more or less prone to automation in the near future. We attempt to do this for Brazil.

Methodology to Assess Automation Risk in the Brazilian Labor Market

Similarly to the U.S. labor market database, O*NET, Brazil has its own classification of occupations. This work does not attempt to identify an automation likelihood of each Brazilian occupation using new experts survey like Frey and Osborne (2017) did. Rather, we assume that similar occupations in the U.S. and in Brazil have the same likelihood of being automatable. For example: if the technology exists to automate away human drivers (autonomous vehicles), then we assume it is technically (but not necessarily economically) feasible to automate car driving in both the U.S. and in Brazil.

With that assumption, the challenge is to match the occupations from the Frey and Osborne study to the Brazilian list of occupations. This effort combines existing conversion tables with manual matching when needed, as detailed in Appendix 3.

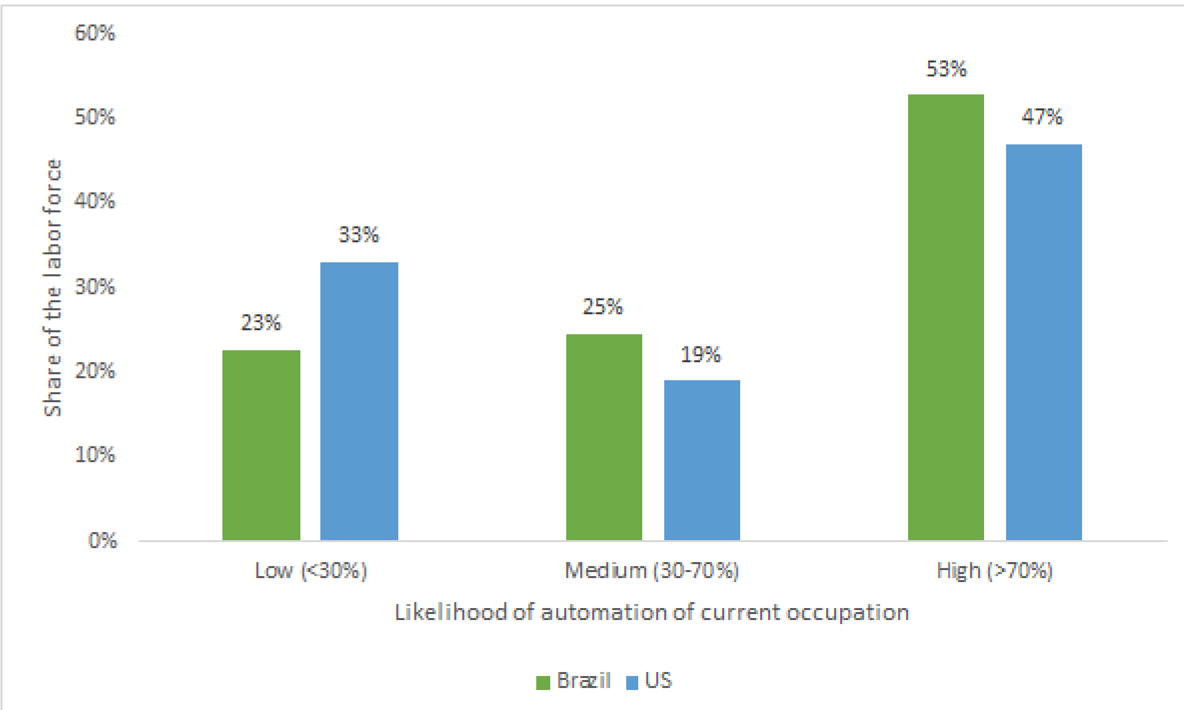
This method allowed us to identify the automation likelihood for 373 occupations in Brazil, out of the total of 433 (86%). These correspond to 85,683,000 people, or 94% or the population that was employed in the second quarter of 2018 in both the formal and the informal labor markets. The remainder of this section is presents the results of this analysis.

Results: Overall Risk of Automation in Brazil

First, at the highest level, we find that the risk of automation in Brazil, considering both formal and informal workers, is substantial: 44.5 million people, or 53% of the employed population, are currently working in occupations with 70% or higher probability of becoming automatable in the next decades (see Chart 4.1 below). Frey and Osborne results for the U.S. indicate that 47% of American jobs have a 70% or higher likelihood of being automatable, suggesting that Brazil's employed population is working in occupations than are even more at risk of automation than the U.S. workforce is.

The results are also more severe than those found in Albuquerque et. al. (2019), which only studied the formal market. That study finds that 55% of the Brazilian formal jobs have a likelihood of 50% or more of being automated. In our analysis, 73% of all - formal and informal - jobs have a likelihood of 50% or higher of being automated. This might indicate that i) the informal market is under higher risk of automation than the formal market from a purely technological perspective, or ii) Albuquerque et. al., (2019) automation likelihoods, calculated based on expert surveys, are sufficiently lower than those of Frey and Osborne as to arrive at different results at the aggregate level, or a combination of both factors.

Chart 4.1. Employed population in Brazil and in the U.S., by risk of automation



Source: For Brazil, authors own calculations based on PNAD (Brazilian National Household Sample Survey), second quarter of 2018, using Frey and Osborne (2017) to determine each occupation's likelihood of automation. For the U.S., Frey and Osborne (2017).

Table 4.1, below, provides the list of top 15 occupations in Brazil by number or people employed, and the corresponding likelihood of automation, converted from Frey and Osborne (2017) as explained in the Methodology. These add up to almost half (45%) of the employed population in Brazil.

Table 4.1. Top 15 occupations in Brazil, by number of people employed, and the likelihood of automation for each.

Occupation name (only top 15) (translated)	Number of people employed	Share of all employed people	Likelihood of automation
Domestic cleaners and helpers	4,786,341	5%	**69%**
General office clerks	3,645,830	4%	**97%**
Shopkeepers	3,293,507	4%	**16%**
Shop sales assistants	3,259,466	4%	**95%**
Mixed crop growers	2,880,806	3%	**61%**
Bricklayers and related workers	2,805,753	3%	**82%**
Cleaners and helpers in offices, hotels and other establishments	2,518,036	3%	**57%**
Car, taxi and van drivers	1,725,270	2%	**98%**
Door to door salespersons	1,716,413	2%	**94%**
Heavy truck and lorry drivers	1,577,098	2%	**79%**
Livestock and dairy producers	1,536,462	2%	**76%**
Building construction labourers	1,480,230	2%	**80%**
Crop farm labourers	1,465,078	2%	Unmatched
Cooks	1,446,830	2%	**73%**
Primary school teachers	1,433,588	2%	**9%**
Total pop. employed (all occupations, including top 15)	**91,234,587**	**100%**	

Source: authors own calculations based on PNAD (Brazilian National Household Sample Survey), second quarter of 2018, using Frey and Osborne (2017) to determine each occupation's likelihood of automation.

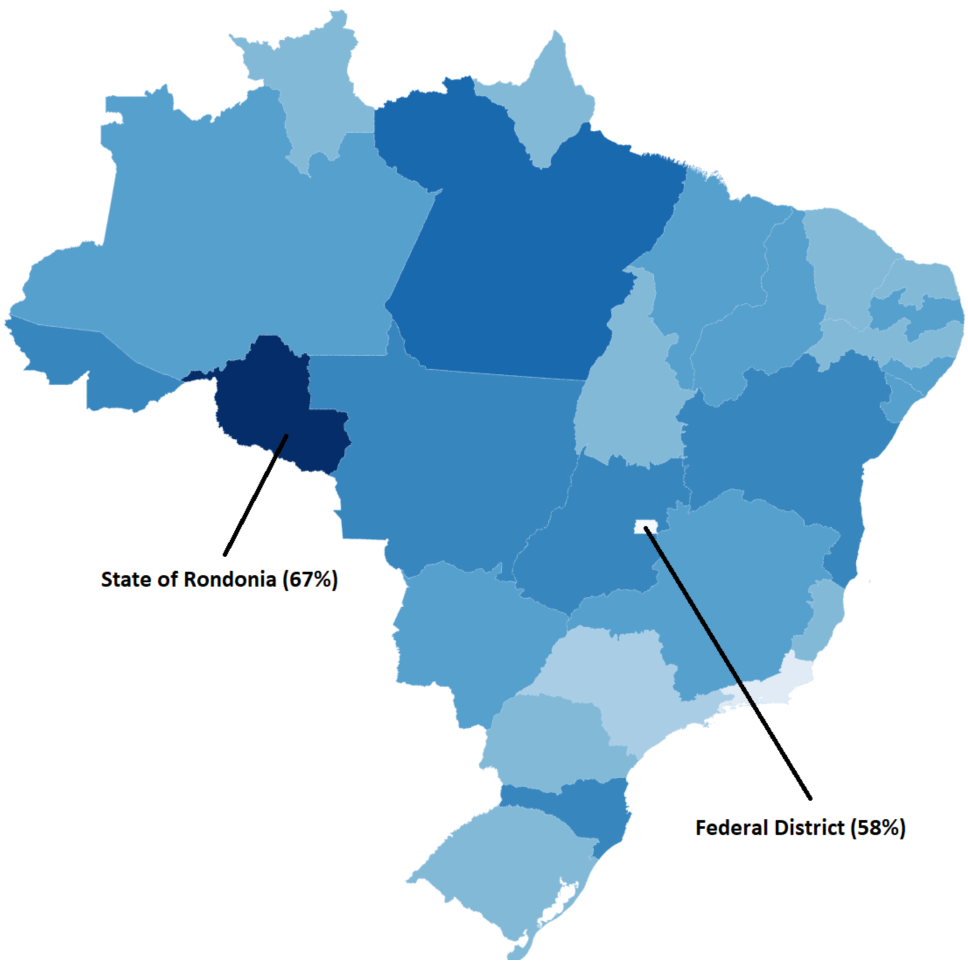
An extended version of the table, including the relevance of each occupation per region in the country, is available in the Appendix 1, and a per-state table can be seen in the Online Appendix.

The next subsections explore in greater detail the profile of workers engaged in occupations that are likely to be automatable in the near future, to better understand what public policies can reduce the risk of unemployment and underemployment.

Characteristics of Populations Under Greater Risk of Automation in Brazil

First we consider the role of geography. Specifically, we look for potential differences between the states in Brazil, considering the aggregated likelihood of automation of the occupations in each state. The results are displayed in Map 4.2.

Map 4.2. Risk of automation per state in Brazil (darker blue means higher risk)



Source: authors own calculations based on PNAD (Brazilian National Household Sample Survey), second quarter of 2018, using Frey and Osborne (2017) to determine each occupation's likelihood of automation.

The difference is not negligible: the state with highest average likelihood, weighted by the number of people in each occupation in that state, is Rondonia (67%), while Rio de Janeiro and Distrito Federal are tied with 59% and 58% in each, respectively. The extremes are labelled in the map above. This means that the occupations commonly found in Rondonia are more likely to be automatable than the ones in Rio de Janeiro and Distrito Federal.

Similarly, there is a meaningful difference between genders: females work in occupations with an aggregate likelihood of automation of 57%, compared with 66% for men.

Secondly, we check whether occupations associated with different income levels also differ in terms of risk of being automatable soon. Here, the difference is pronounced: as can be seen from the Chart 4.3, most of the Brazilian employed population makes less than the equivalent of 2 Brazilian minimum wages (USD 523.28, as of January 2019), but these are also the ones in occupations under higher risk. Higher labor income is strongly associated with occupations with less risk of automation: the likelihood drops from almost 70% for lower paid workers to less than 30% for those making over 10 MWs (USD 2616.40). This is especially relevant in a country like Brazil, were inequality levels are already among the world's highest for which we have data (Alvaredo et. al, 2018).

Thirdly, we investigate the age pattern and the likelihood of automation, among the employed population. The result is displayed below, in Chart 4.4. Although the automation likelihood is somewhat stable around 60% for formally or informally employed people in their thirties and older, the numbers for younger populations are even higher. In particular, those in their twenties or younger are working in occupations with, on average, 70% or higher likelihood of being automatable. This suggests that, if automation indeed follows from the technological capacity to automate, the younger in Brazil might suffer disproportionately. This can have long-lasting consequences as it affects the early stages of professional careers.

A closer look at the younger would be incomplete without understanding how education is associated with the likelihood of automation. Similarly with the labor income analysis, the result is very pronounced, as shown in Chart 4.5. While the aggregated likelihood of automation is near 70% for those with 10 years of education or less, this risk goes down progressively if one goes into high school, and sharply declines for those with 15 or more years of education. The implication is that occupations associated with college degrees are under substantially less risk than lower skilled occupations. In a country like Brazil where, according to the National Survey data, only 18% of the population has a college degree, the result can imply profound consequences for poverty and inequality levels.

Albuquerque et. al., (2019) states that "the main feature of all OECD countries is that the automatability frequently decreases in the level of education and in the income of the workers". (p. 5). The analysis presented above suggests that the same is true for Brazil. We find that the likelihood of automation is highest for men than for women, for people employed in occupations with wages below 2 Brazil's minimum wages, for people with less than 12 years of education, and for the youth under the age of 24.

<u>Chart 4.3. Employed population per income level in Brazil, and the risk of automation</u>

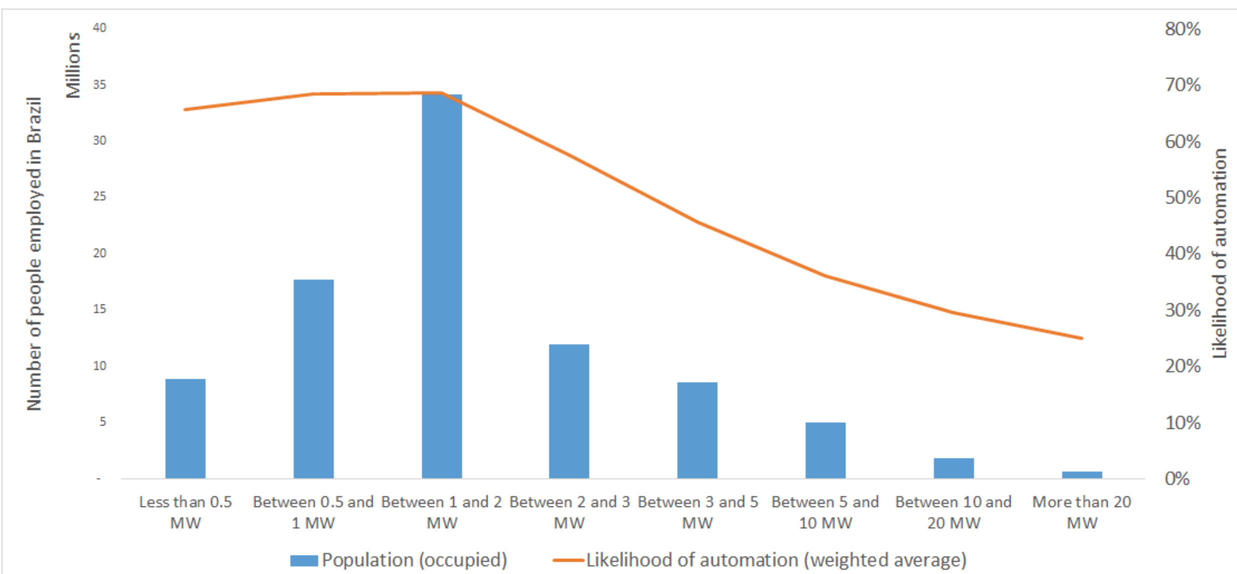


Chart 4.4. Employed population per age bracket in Brazil, and the risk of automation

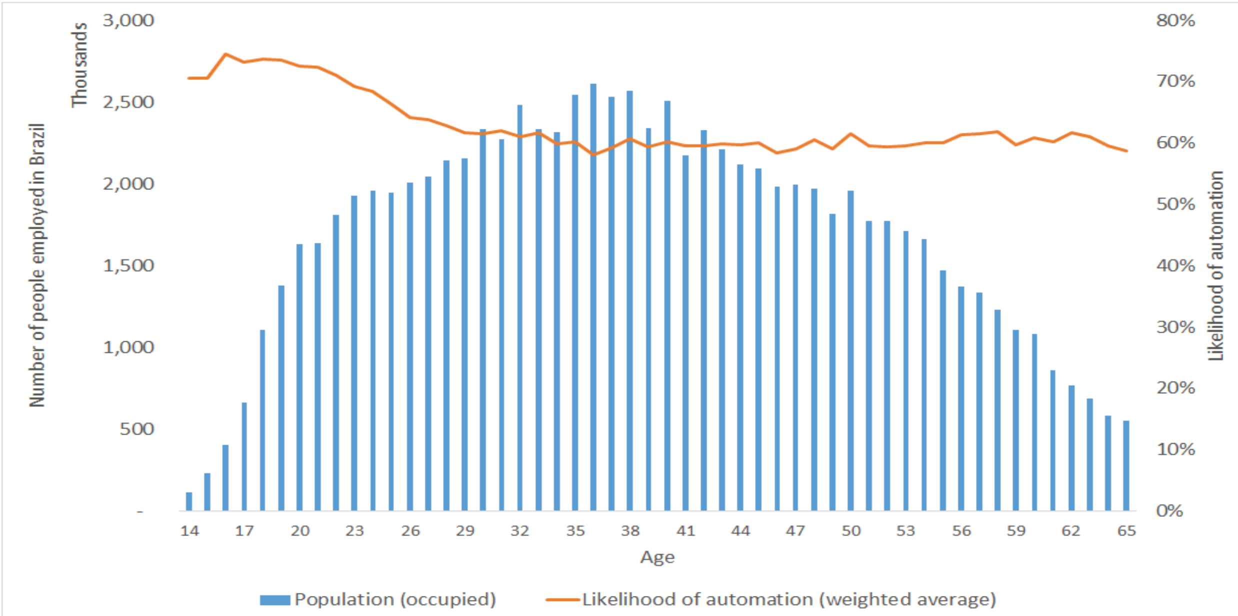
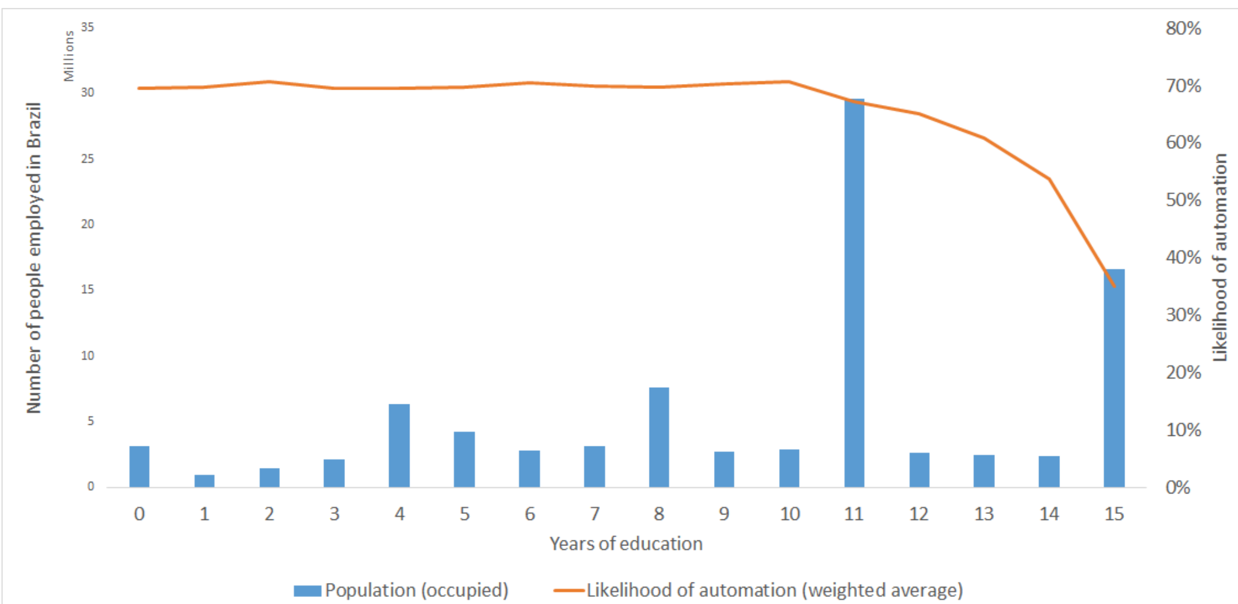


Chart 4.5. Employed population per years of education in Brazil, and the risk of automation



Source: authors own calculations based on PNAD (Brazilian National Household Sample Survey), second quarter of 2018, using Frey and Osborne (2017) to determine each occupation's likelihood of automation. In Graph 4.3, MW stands for the Brazilian Minimum Wage, which was R$ 954 in 2018 (equivalent to USD 261.64, in the exchange rate of January 2019).

5. Selecting a Policy Approach: Protect the Jobs or Protect the Workers?

The Appeal and Dangers of Digital Protectionism

As discussed above, it is not implausible that income distribution effect of intelligent automation will be the biggest for skill-poor countries that will be cut off from the opportunity to industrialize leveraging wage differentials (Rodrik 2018; Cowen 2018; Tirole 2017); moreover, industrialization has already peaked at a comparatively low level for many developing countries, including Brazil (Rodrik, 2017). The analysis in the previous section confirms that there is a real risk of inequality in Brazil increasing as a result of increasing levels of automation in the world. As Cowen (2017) notes, cross-country distributional effects are much harder to address than those within nations, because voters are a lot less likely to support income redistribution outside their borders comparing to within them.

In addition, following the discussion in Weber (2017), a "data periphery" country — a country exporting raw data and importing high value-added data- and AI-enabled services — can easily get trapped in a persistent development disadvantage and see its ability to develop a dynamic domestic industry producing higher value-added AI products progressively diminish, since the properties of AI-based services make it such that the more data the service collects, the faster it improves, penetrating the market further and further. Given these conditions, a "data periphery" country will soon find itself dependent on foreign service platforms, which might be concentrated in a handful of advanced economies well endowed in top quality talent and benefitting from the cluster economy effects.

As discussed by Mateos-Garcia (2018), it is to be expected that deployment of AI will be more extreme-paced in industries where workers have less influence, education and affluence (i.e. "gig" economy platforms, e-commerce, etc), further exacerbating unfavorable economic conditions in "data-periphery" countries.

The above considerations, as well as an obvious conceptual parallel between AI-induced shocks to comparative advantage and trade liberalization, naturally lead one to consider the case for "digital protectionism" — regulation that through a variety of means disadvantages the local operation of foreign platforms and supports the infant local ones.

The same parallel with trade liberalization draws many to dismiss protectionist measures as an outright backwards idea (Summers, 2017). And indeed, such measures certainly come with substantial risks, including slowing down innovation at the time when developing countries need it more than ever. Bureaucratic dysfunction often converts protectionism into rent extraction, and Latin America in particular has an unfortunate history of that.

While acknowledging the magnitude of the aforementioned risks, we believe a more nuanced consideration is due here. While digital protectionism is definitely not in the best interest of a handful of countries owning the dominating platforms producing AI- and data-driven services, a path of thoughtless openness does come with a risk of permanently placing countries dependent on those services at the bottom of the global income distribution. As Weber (2017) concludes, for such countries protecting and subsidizing the development of local platforms might be critical for retaining the prospect of a robust economic growth in the future, even though it comes at a short term direct cost to local consumers who receive a smaller selection of potentially lower quality services.

In particular, a nuanced legislation around data protection and ownership is necessary, no matter the chosen level of openness to foreign platforms and technologies; Brazilian legislators made a lot of progress on this front and passed the General Data Protection Law in August 2018. Legislation regulating data collection and usage is necessary not only to ensure the protection of rights of domestic users, but it might also play a critical role in enabling domestic producers to compete with foreign players in AI services that depend on ability to train algorithms on large amounts of high-quality local data.

Just like with trade integration, it might often be beneficial to open to new technologies gradually, more proactively managing the pace of disruption and allowing local workers and firms to have more space to adjust.

Having said that, the authors of the present work do not intend to advocate for restrictive digital barriers that would shelter Brazil (or any other country, for that matter) from the changes to the global economy being brought about by rapid advancements in AI. While informed and nuanced approach is warranted and might bear real results in terms of creating more favorable conditions for local AI-enabled services ecosystem to develop, any dramatic protectionist measures would be harmful in the long term, and often even infeasible to implement in practice.

Digital protectionism should be thought of with extra-caution in the case of Brazil in particular, given its history of responding to increasing integration of the global economy by essentially remaining largely closed to trade—Brazil's share of trade as a percentage of GDP has remained one of the lowest in the world: in 2017, Brazil's imports were at 11.55% of GDP, exports at 12.57% of GDP (World Bank Open Data). In Brazil, therefore, short-term trade protectionism has effectively become a long-term policy. If in response to a shock to comparative advantage brought about by advances in intelligent automation Brazil introduces de-facto long-term digital protectionism measures, it runs a risks of missing out on a key opportunity to boost productivity in the economy that has been struggling to raise it for a while (see Section 3).

No matter the amount of digital protectionism that Brazil will choose to greet the advancements in intelligent automation with, it is likely inevitable that its economy will experience at least a fraction of the consequences of the rapid spread of AI and robotics. For this reason and per the recommendation of Flanagan and Khor (2012), as cited in OECD 2018a, we will focus the rest of our discussion of policy alternatives on the options aimed at protecting Brazil's domestic workers, not its jobs or industries.

6. Analysis of "Protect the Workers" Policy Alternatives

The increasing adoption of intelligent automation is a historically recent phenomena. Most of the work and research we build on was developed in the past 4 or 5 years at the most. For that reason, the policy alternatives for making workers more resilient to automation have not been tested enough as to provide guidance on what is more effective for a given country. In this section, we consider some of the ideas being discussed in academic and policy circles, as well as their applicability in Brazilian context discussed in the previous sections, and suggest ways to amend programs already in operation in Brazil. For each, we consider if, in Brazil's context, they are technically correct, administratively feasible and politically supportable.

Option 1. Universal Basic Income and its Applicability in Brazil

Universal Basic Income (UBI) is one the most frequently discussed measures suggested as a response to potential unemployment or underemployment caused by intelligent automation. It seems to be making its re-entry into mainstream policy debate in the rich countries; in the U.S., one of presidential candidates for the 2020 election is running on a platform based primarily on a proposal to give every U.S. citizen of the age of 18 $1000 per month, "no strings attached" (Yang, 2019): enough to provide for minimal needs, but not enough to eliminate the incentive to participate in productive economy and earn more.

As noted by Yuval Harari (Marconi 2018), the name Universal Basic Income is misleading, a better name would "National Basic Income," unless those suggesting it have a truly global redistribution scheme in mind, which in most cases they do not. With this in mind, and consistently with the common usage pattern, will proceed by calling a nation-wide benefit scheme "universal".

There have been a few programs piloting UBI mostly on a local scale in both developed (Finland, Germany, Canada) and developing countries (Kenya), where it is funded by Give Directly, an NGO. More and longer studies are necessary to extract robust conclusions about the effects of UBI, but the conceptual appeal of it in the face of potentially accelerating automation is clear: if technology "hollows out" mid-level wages, contributing to an increase in inequality, in absence of redistribution that inevitably threatens consumer demand. Giving people cash would ensure sustained demand, which, in its turn, can help fuel economic growth. As cited by Brynjolfsson and Mcafee (2014), over the years the proposals of guaranteed income have been supported by both conservative (M. Friedman, F. Hayek) and liberal (J. Tobin, P. Samuelson, J.K. Galbraith) economists. Yang's 2020 campaign cites Nikiforos et al. (2017) study that modeled the macroeconomic effects of UBI and projected a permanent increase in GDP of 12.56-13.1%.

Turning to Brazil, even if we accept as a theoretical possibility that in a long term UBI can help generate enough growth to "pay for itself", it is virtually inevitable that it will generate a large fiscal deficit at least in the short term. In a country that has constitutionally committed itself to a 5% per year fiscal adjustment, but is struggling to keep its large and mounting debt on a sustainable path, it is difficult to even include UBI into a serious consideration set due to the lack of fiscal space for it—the danger of making the debt unsustainable is too great to be dismissed.

Brazil passed legislation necessary for implementation of a UBI-like benefit in 2004 (Federal Law 10.835); the law prescribes the amount of the benefit to be the same for all citizens and "enough to meet the needs concerning food, health and education". Even if the size of the benefit is set to as low as half of Brazil's current minimum wage (R$499 or USD 129 per month), fiscal consequences would be dramatic: as of 2019, the aggregate cost of such program would be USD 324 billions per year, or around R$ 1.2 trillion—more than 15% of Brazil's GDP. Even if these costs can be partially offset by reductions in healthcare and other public spending, the remaining weight of the fiscal burden is hard to underestimate.

Brazil may potentially consider a form of guaranteed income or negative income tax at a later date should its debt burden recede, but we will refrain from speculating on when that might occur, and deem the measure out of reach given Brazil's current fiscal situation and the level of debt. At present, however, UBI is not only unaffordable, but most importantly does not efficiently help to strengthen Brazil's human capital resource, its competitiveness, and, by extension, Brazil's ability to capitalize on the development and adoption of intelligent automation.

Assessing political supportability of UBI in Brazil requires some speculation since it is not currently being discussed in the public policy circles. We believe a proposal of any UBI-like benefit runs a risk of being highly unpopular due to an extreme level of wealth and income inequality in Brazil, which is one of the worst in the world (World Bank Data Bank, 2019).

That said, the legislation, administrative capacity and financial infrastructure for managing a country-wide cash transfer program is definitively in place in Brazil, which has been running Programa Bolsa Familia, one of the largest conditional cash transfer programs in the world for more than a decade, and reached a high level of banking penetration among the population: according to World Bank 2017 Global Findex, 70% of adults have a bank account. For that reason, from an administrative point of view, UBI could be rolled out quickly in Brazil, shall the resources and political will appear.

As the above discussion suggest, Universal Basic Income, unless it is funded by third-party organizations or advanced economies, is completely out of reach of many developing economies, especially those overburdened with existing debt.

Option 2. Life-Long Training Accounts

Another idea widely discussed in the policy circles of mature economies is Life-Long Learning and Training Accounts (LLTAs). Different proposals of such accounts have been floated in recent years, with details varying from country to country, but the most common design features include a tax-advantaged savings account, in which individual's savings are matched by the government and, possibly, the employer; accumulated funds can be used to pay for training from certified providers or, in some design proposals, as income support in cases of un- or underemployment (Fitzpayne, Pollack 2018). Currently, France is piloting a Personal Activity Account (Le Compte personnel d'activité, CPA), a "portable benefit system that seeks to establish a universal right to training" (Randolph, Dewan 2017).

At present, it would be unrealistic to expect all workers in occupations susceptible to automation in Brazil to participate actively in an LLTA-like programme, given the very low national savings rate in Brazil despite high interest rates: according to World Bank 2017 Global Findex, only 7% of Brazilian adults are saving for retirement, and only 32% were able to make any savings at all in the last year. Thus, instead of asking people to save in order to fund their own future training needs, a more feasible scenario would be to expand an existing government- and/or employer-funded programs to cover training expenses, and ideally not only for the already unemployed, but proactively for those identified as at risk of unemployment.

Brazil has two parallel unemployment insurance schemes (OECD 2018a): Seguro Desemprego, which provides monthly benefits for 3-5 months to those who lost their formal private sector job, and FGTS (Fundo de Garantia por Tempo de Servico, Guarantee Fund for

Length of Service)—a system of individual unemployment accounts primarily funded through an employer's contribution (8% of employee's wage), and government matches. The Fund can be accessed by a worker in a very restricted set of circumstances: upon an unjustified dismissal (dismissal without reason), death, terminal illness or retirement. According to OECD (2014), FGTS has consistently performed significantly below market rates, with returns being poor and sometimes even negative; it has created perverse incentives for both employees and employers which might be increasing worker turnover (i.e. the cases of workers asking to be formally fired instead of quitting are reported to be frequent), even though fairly similar funds have performed well in some other OECD countries, most notably Austria (OECD 2018a).

In order to be suitable to provide protection in case of job loss due to automation, FGTS access conditions need to be expanded beyond the exceptional circumstances only, and allow for savers to make drawdowns to cover training-related expenses even while they are employed, which is not possible under the current law regulating FGTS. If passed legislatively, this change will likely lead to the funds being accessed more frequently, including potentially for the reasons of expended possibilities for fraud through rollback schemes with rogue training providers. This might put on a strain on the solvency of the programme. But even if these administrative difficulties of the programme implementation could be resolved, given the Fund's consistently poor financial performance and its use to fund infrastructure projects, we do not recommend to rely solely on FGTS as a sufficient measure to ensure resilience of workers to intelligent automation.

Option 3. Customizing Existing Vocational Training Programs Using Likelihood of Automation and Skills Proximity

Brazil, like many other countries, already has vocational training programs available to adults with various levels of education. How can those programs be amended to help workers and the economy become resilient in the face of intelligent automation?

In October 2011, the Federal Government of Brazil created National Program of Access to Technical Education and Employment (PRONATEC) through a new "umbrella" law 12,513.

As stated in the law, the aim of Pronatec is “to expand the offer of vocational and technological education courses through technical and financial assistance actions.” According to the Ministry of Education, among other measures, PRONATEC sets out to “to increase the educational opportunities of workers” in partnership with the Federal Network of Professional, Scientific and Technological Education, national apprenticeship institutions, as well as qualified private educational institutions.

In 2018, OECD conducted a comprehensive review of PRONATEC, and suggested, among others, the following improvements (OECD 2018b):

- Align vocational training offering with labor market needs by conducting regular region-specific and sector-specific Skills Assessment and Anticipation (SAA) exercises that PRONATEC currently lacks, which frequently results in an educational partner offering the cheapest to provide courses as incentivised by the current provider compensation scheme (fixed payment per hour per lerner);
- Adapt the amount financial and other support to trainees to their socio-economic conditions (currently everyone received the same amount of support);
- Create a training voucher system and a career guidance service helping individuals choose a training from a region-specific catalogue.

In order to specifically address the concern of workers’ resilience to intelligent automation, we suggest amending the above list of improvement ideas with the following:

1. To update the regional catalogues of trainings, complement the SAA exercise with a consideration of medium to long term automatability of occupations: aside from helping to satisfy the immediate labor market needs, the training offering should contain courses that help individuals acquire skills that will enable them to move into occupations less susceptible to intelligent automation in the medium to long term. This is especially relevant given that many workers do not have an opportunity to dedicate a sizable amount of time to training more frequently than once every few years, hence the skills they acquire need to serve them well beyond the short term only. An important caveat here is that our ability to predict which occupations will be automated and when is very limited (Johal 2018), hence training offering adjustments need to be undertaken with extreme

caution. That said, if an individual is taking time out of her schedule to learn new skills, it is generally desirable to ensure to the best of our ability that she is acquiring durable skills, which will remain relevant with high degree of probability for years to come.

2. Incorporate considerations of susceptibility to automation into career guidance services: for individuals in occupations prone to intelligent automation, it is easier to move to occupations that make use of a similar or overlapping set of skills as their current occupation. It would thus be valuable if a career guidance service could help individuals identify occupations that satisfy both requirements: being as similar as possible to their current occupation in terms of skills utilized, while also less susceptible to automation than the current occupation. Such identification can be made possible using, for example, Knowledge-Skills-Abilities proximity trees similar to the ones constructed in Diodato, Neffke, Nedelkoska (2018) - see Appendix 2 for a sample tree. Next, the career guidance service could help locate the training course necessary to develop the missing set of skills that differentiate the desired occupation from the current one.
3. Anticipate student inflows based on the assessment of which occupations are likely to be impacted by automation in the medium term, and ensure there exist training offerings that will help them move into a less-prone-to-automation occupations with minimal amount of time spent in re-training.

Considering the costs of the customization of vocational training programs, depending on the design it can be a relatively affordable option. The Secretary of Social and Productive Inclusion, Vinicius Botelho, mentioned in interview for this work that any attempt to improve quality of vocational training programs would have to address the question of incentives alignment for the private providers of the service. Consider, for example, a pay-for-performance contract with the private providers of training, attached to the jobs and wages obtained by the beneficiaries after the program. This design is not only incentive-compatible but would also generate additional fiscal revenue, by moving people from unemployment or informal employment to the formal sector. At least in theory, considering Brazil's high labor taxes, it could even be that a well-designed, pay-for-performance vocational training program would generate enough (new) tax revenue stream as to offset completely the program's cost.

Comparing Policy Alternatives

Table 6.1 summarizes our assessment of implementation time and estimated cost of each of the three policy alternatives described above. Table 6.2 summarizes our assessment of Technical Correctness, Administrative Feasibility and Political Supportability of each of the three policy alternatives described above.

Table 6.1 Implementation time and Estimated Cost of the policy alternatives.

	Implementation Time	Estimated Cost
Universal Basic Income	**Within ~2 Months*** *assuming funds availability; legislation and infrastructure are in place	**15% of GDP/Year** Assuming each person to get half a min wage per month
Life-Long Training Accounts (FGTS reform)	**Potentially Long** Law amendment is required to expand FGTS scope; fixing administrative flaws can take unpredictably long	**Virtually Zero** The program exists; is currently funded via employer contributions
Customization of vocational training programs	**Within a Year** Requires limited capacity building at the regional level	**Virtually Zero** A pay-for-performance contract could generate new tax revenue stream and could offset the program's cost

Table 6.2. "Trinity" assessment of policy alternatives.

	Technical Correctness	Administrative Feasibility	Political Supportability
Universal Basic Income	**Low** Doesn't help to retain competitiveness	**High** Brazil runs an extensive CCT that can be scaled	**Low** Very bad optics in a highly unequal country
Life-Long Training Accounts	**Medium** Kow private savings create barriers for scalability	**Low** FGTS has a long history or poor or negative returns	**High** FGTS is unpopular, changes are welcomed
Vocational training program adjustment	**High** Builds human capital, improves competitiveness	**Medium** Requires limited capacity building at little to no cost	**High** Education programs are traditionally popular

7. Final Recommendation

As the analysis presented in Section 4 demonstrates, among the 15 most common occupations in Brazil, which correspond to 45% of the national workforce, the likelihood of automation exceeds 85% probability for the following five that are likely to be in need of a targeted re-training program offering:

- General office clerks: 97% likelihood of automation, 3.6M people or 4% of the Brazilian workforce;
- Shop sales assistants: 95% likelihood of automation, 3.3M people or 3.6% of the workforce;
- Door-to-door salesperson: 94% likelihood of automation, 1.7M people or 1.9% of the workforce;
- Car, taxi and van drivers: 98% likelihood of automation, 1.7M people or 1.9% of the workforce (heavy truck drivers have a slightly lower likelihood of automation - 79%, 1.6M people or 1.7% of the workforce are employed in this occupation);
- Security guards: 89% likelihood of automation, 1.3M people or 1.4% of the workforce;
- Cashiers and ticket clerks: 90% likelihood of automation, 1M people or 1.1% of the workforce.

Of course, even in the most disruptive scenario of a high-paced intelligent automation affecting specifically these occupations, not everyone will be displaced at the same time, even if certain occupations get completely eliminated in the long run. However, it is not unreasonable to expect gradual contraction of labor demand for these occupations, mounting downward wage pressure, and/or significant changes in skills required in the corresponding jobs. Estimations of the susceptibility to automation, even though imprecise, allow to make proactive adjustments to the existing unemployment benefits schemes and retraining programs, to prepare them to help workers bounce back faster from the kind of changes in labor market demand that can be triggered by intelligent automation in the next decade.

Since 2014, many of Brazilian vocational training programs under the umbrella of PRONATEC have lost most of the government funding, after several program evaluations showed little, if any, effect on employment for the beneficiaries. The vocational training program that replaced it, aiming to fix some of the identified flaws, is Progredir, aimed at generating employment and income for people enrolled in Cadastro Unico—the single registry of the poorest households in the country. In order to proactively build the resilience of workers faced with the prospect of rapid advancement in intelligent automation technologies, vocational programs need to be i) incentive-compatible for private providers of training, and ii) accessible for both the poorest among the population, and other groups identified above as being at risk of getting most impacted by the changing profile of labor market demand for skills. This can be done by broadening the scope and scale of Progredir, improving its design to address the shortcomings mentioned in the previous section.

Finally, the by-regional data on the likelihood of automation of top occupations provided in Appendix 1 can serve as an input in the selection process of Progredir training course offerings and the design of their targeting and outreach efforts. We suggest to complement the Skills Assessment and Anticipation exercises with a consideration of medium to long term automatability of occupations: aside from helping to satisfy the immediate labor market needs, the training offering should contain courses that help individuals acquire skills that will enable them to move into occupations less susceptible to intelligent automation in the medium to long term. Proactively taking automation likelihood into account will allow to anticipate the skills and needs of future incoming streams of students who will be turning to training to maintain their competitiveness in the face of labor market changes triggered by intelligent automation, as well as minimize the time the students need to spend retraining before they can move into a new occupation less prone to automation.

8. Conclusions and Further Research Directions

In the last two decades, Brazil has had a negative net productivity growth, and maintained one of the lowest in the world shares of trade-to-GDP. Allowing for a greater degree of openness and faster adoption of emerging technologies holds a promise of helping to reverse the declining productivity trend, but comes with a risk of labor displacement, which is particularly severe for the poorest, the young, and the less educated.

This paper assessed the present-day applicability of the three commonly suggested ways to improve workers resilience in the face of intelligent automation—universal basic income, life-long training accounts, and vocational training programs. We discard UBI as not only prohibitively expensive, but also not particularly helpful for building Brazil's human capital, its competitiveness, and, by extension, its ability to capitalize on the development of intelligent automation. Expanding Brazil's unemployment insurance program to cover proactive training expenses, while being useful for building human capital, is not immediately implementable as it requires legislative changes and reversing the historically poor performance of the unemployment insurance fund. When it comes to vocational training program, virtually costless changes to the selection of courses that are made available in each region can go a long way in helping to prepare the labor force for the age of intelligent automation.

As this paper focused on finding the most feasible immediate-term steps that can be taken by the national government to help Brazil prepare its economy for successfully weathering the shocks to comparative advantage that might come from the rapid advancements in the adoption of intelligent automation technologies around the world, a few broader topics were left outside of the scope of the present work, but would be vital to consider for making the country's long-term development strategy fit for the age of AI. Those topics include, but are not limited to, the questions of industrial policy and nurturing domestic high-value-added AI- and data-enabled products and services; questions of attracting and retaining high-skilled talent; approaches to taxation of international technology companies, as well as the effects of labor costs and taxes on the incentives to create or adopt labor-saving technologies.

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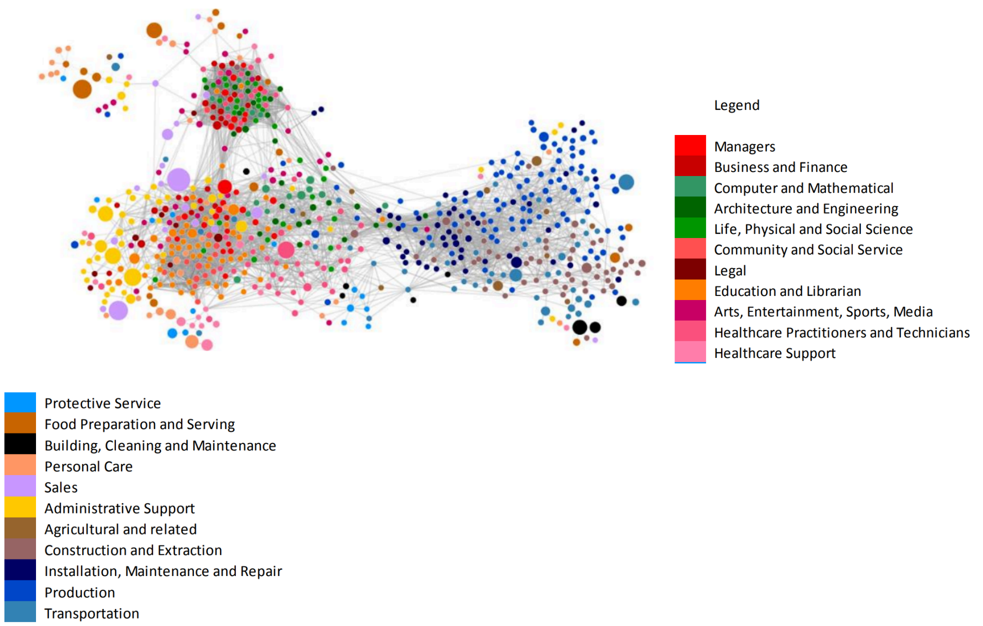
Appendix 1. Occupations and Automation by Region in Brazil

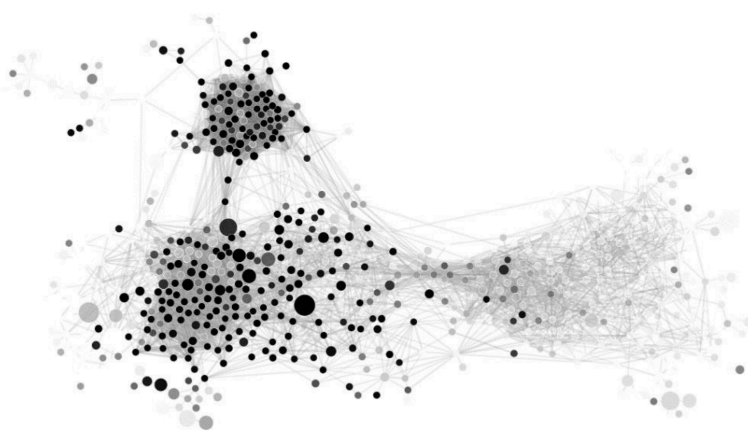
Occupation name (translated)		Share of all exployed people	Likelihood of automation	Sul 1	Sudeste 2	Centro Oeste 3	Nordeste 4	Norte 5
Domestic cleaners and helpers	4,786,341	5%	69%	436,999	2,250,276	358,564	1,143,472	597,030
General office clerks	3,645,830	4%	97%	436,388	1,608,130	322,555	757,666	521,090
Shopkeepers	3,293,507	4%	16%	237,424	1,219,121	229,999	1,121,640	485,323
Shop sales assistants	3,259,466	4%	95%	351,310	1,485,632	226,808	774,501	421,215
Mixed crop growers	2,880,806	3%	61%	464,159	682,403	52,583	1,084,222	597,439
Bricklayers and related workers	2,805,753	3%	82%	321,960	1,313,002	187,631	564,585	418,574
Cleaners and helpers in offices, hotels and other establishments	2,518,036	3%	57%	245,192	1,140,700	195,020	573,985	363,139
Car, taxi and van drivers	1,725,270	2%	98%	136,207	866,975	105,228	433,405	183,456
Door to door salespersons	1,716,413	2%	94%	164,715	678,539	113,873	483,475	275,811
Heavy truck and lorry drivers	1,577,098	2%	79%	246,553	681,706	141,618	256,816	250,404
Livestock and dairy producers	1,536,462	2%	76%	258,833	356,319	234,126	330,508	356,675
Building construction labourers	1,480,230	2%	80%	111,840	570,233	87,255	496,935	213,966
Crop farm labourers	1,465,078	2%	-	84,574	499,067	39,460	659,294	182,683
Cooks	1,446,830	2%	73%	150,962	624,618	124,444	329,245	217,561
Primary school teachers	1,433,588	2%	9%	131,724	511,441	98,663	472,041	219,719
Security guards	1,312,459	1%	89%	114,513	568,458	101,805	349,970	177,713
Hairdressers	1,155,215	1%	11%	105,807	591,063	77,617	263,848	116,880
Motor vehicle mechanics and repairers	1,093,911	1%	65%	125,463	434,885	97,099	269,867	166,597
Beauticians and related workers	1,030,194	1%	37%	79,581	574,862	74,329	189,998	111,424
Cashiers and ticket clerks	1,004,088	1%	90%	125,164	495,364	67,447	187,989	128,123
Total population employed in top 20 occupations	**41,166,575**	45%						
Total population employed in all occupations	**91,234,587**	100%						

See Online Appendix for the occupations' conversion table and by state information on occupations and automation likelihood. Available at: https://bit.ly/2RuyqcO

Appendix 2. Knowledge-Skills-Abilities Proximity Trees



Source: Diodato, Neffke, Nedelkoska (2018).
Nodes are occupations; distances between them represent degree of similarity based on knowledge, skills and abilities required for those occupations



Source: Diodato, Neffke, Nedelkoska (2018).
Brightness of nodes represents the likelihood of the corresponding occupations to be automated.

Appendix 3. Methodological Description

Understanding Frey and Osborne (2017) Methodology

In short, Frey and Osborne asked (unidentified) experts to hand-label whether a given occupation from the US labor database (O*NET) could, technically speaking, be fully automated in the near future (binary question). The exact question was "*Can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by state of the art computer-controlled equipment*" (Frey and Osborne, 2017, p.263).

The expert's confidence level on their own predictions varied, and the affirmative answer (can be automated) was only given when experts said they were strongly confident about their guesses. This was done for 70 occupations. Based on the skills associated with these 70 occupations, the authors extrapolated the results for a broader list of 702 occupations, using machine learning to establish the probability that each of them could be automated.

The intuition is as follows: if truck drivers were classified as "for sure will be automatable" by the experts, while senior public officers were considered impossible to be automatable, then an occupation that requires essentially the same skills of a truck driver would also have a very high probability of being automated, while one that was closer to the skills of a senior public official would not. A hypothetical occupation that requires the skills of truck drivers and the skills of senior public officials in equal frequency would, in theory, have a 50% chance of being automated.

Adapting Frey and Osborne to Brazil's Data

This work has not attempted to manually or semi-manually assess the automation likelihood (see Box 1) of any occupation; instead, we use the work of Frey and Osborne for that. Specifically, we assume that for a given occupation in the U.S., the corresponding occupation in Brazil has a similar likelihood of being automatable soon. For example: if there is a 98% chance that the technology to automate a taxi driver will exist in the near future, then this is relevant for taxi drivers both in the US and in Brazil (and elsewhere), especially because the commercial viability of the automatized solution (here, probably an autonomous vehicle) is not considered in this work (or by Frey and Osborne),

The challenge, therefore, is to match the occupations used by Frey and Osborne (based on O*NET dataset) to the Brazilian context.

We do this in two steps: i) matching U.S. data (O*NET) to the international standard ISCO-08, and then ii) matching ISCO-08 to COD (Brazilian classification of occupations used in national surveys)[1].

The advantage of using Brazil's COD is that it allowed us to map each occupation to Brazil's national survey, PNAD Contínua (Brazilian National Household Sample Survey), that is undertaken 4 times per year, interviewing over half a million people, and including a wide range of demographic and geographic variables that allow for a greater understanding of the economic relevance and profile of people engaged in each occupation.

There are other ongoing attempts to better understand the impact of new technologies in the Brazilian labor market. Albuquerque et. al. (2019), unpublished, uses new experts' inputs, along the lines of Frey and Osborne (2017), for Brazilian occupations. The dataset used is Brazilian Annual Social Information Report (Relação Anual de Informações Sociais – RAIS). According to the authors, 55% of Brazilian *formal* jobs are under risk of automation.

There are two main differences between Albuquerque et. al. (2019) and this work. First, and as mentioned above, we do not attempt to reclassify from scratch the automation likelihood per occupation in Brazil. Instead, we use conversion tables and assume that for a given occupation in the U.S., the corresponding occupation in Brazil has a similar likelihood of being automatable soon, as mentioned above.

[1] We are deeply grateful for the support and generosity of multiple people along this conversion effort. For step 1 we thank Prof. Ljubica Nedelkoska (Harvard Kennedy School); for step 2 we relied on conversion table provided by the Brazilian Institute of Geography and Statistics – IBGE (unpublished). The conversion file can be checked in the following link: https://bit.ly/2RuyqcO.

Secondly and perhaps more crucially, we use PNAD and not RAIS as our dataset. Even as RAIS is designed to provided more complete data on the labor force, it is restricted to the Brazilian formal market. PNAD, on the other hand, is representative of the country's population and also at the state level, and it includes both the formal and the informal markets. Unlike in the U.S., the informal market is responsible for almost half of the employment in Brazil: there are around 46 million formal jobs in Brazil (Albuquerque et. al., 2019) and 45 million informal jobs, according to our own analysis - the later are typically associated with the most vulnerable populations. Therefore, any public policy that attempts to mitigate risks and losses associated with rapid changes in the labor market should include the informal sector if it is to include those under worse socioeconomic conditions.

By matching U.S.'s O*NET to Brazil's COD as described, we could identify the automation likelihood for 373 occupations in Brazil, out of the 433 (86%). These correspond to 85,683,000 people, or 94% or the employed population in the second quarter of 2018.

Because there is data on the automation likelihood for 702 occupations (from Frey and Osborne, 2017) and there are only 433 occupations in the Brazilian COD, sometimes multiple O*NET occupations matched one single Brazilian occupation on COD. This happened in 238 instances out of the 373 matches. In these cases, by default we used the simple average of the automation likelihood of the multiple O*NET occupations and applied it for the corresponding Brazilian occupation. However, in 126 out of the 238, the variance of the multiple automation likelihoods was very high (over 0.1), suggesting that that average was hiding meaningful differences in the automation likelihood - and therefore deserved a closer look. So for these cases we manually inspected each average and, in 84 out of 126 cases, opted to select a single O*NET occupation that was a closer match with the Brazilian COD occupation. For full transparency, the list of all manual changes are included in the Online Appendix, available at: https://bit.ly/2RuyqcO.

Appendix 4. Brazil in Automation Readiness Index

Source: The Economist Intelligence Unit and ABB, The Automation Readiness Index: Who is Ready for the Coming Wave of Automation, 2018. Retrieved from: http://www.automationreadiness.eiu.com/.