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Labour market transformations in the era of new technologies: an analysis by regions, gender and industries in Brazil

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The Future of Work(ers) Research Project explores how digital technologies are reshaping the world of work and the impact of these changes on inequality. It conceives of the development and application of digital technologies as a contested terrain. It is particularly interested in how collectives of workers are shaping which digital technologies are developed, how and to what end; and the economic and social policies that have been leveraged in response.

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Abstract:

The impact of new technologies on the workers is the subject of intense debate. However, a deep analysis of the global South qualifying their regions' inequality is rarely addressed. We evaluated the Brazilian formal labour market, unpacking disparities according to regions, manufacturing sub-sectors, and gender. First, we created a compatibility table of the occupation list provided by Frey and Osborne (2017) and the Brazilian occupations list to identify the occupations with a higher and lower digitalisation risk. Second, we elaborated a granular view of such occupations using different dimensions (five regions, 23 industries, three technological groups and gender). Third, we analysed the employment change between 2011 and 2019 to promote a comprehensive view of the drop in employment in the past decade. Results showed that most jobs in the Brazilian manufacturing sector are in occupations at high risk of digitalisation but that there is substantial heterogeneity regionally, sub-sectorally, by gender and for all region-gender-sub-sector combinations. The proportion of women workers is smaller than the proportion of men in almost all sub-sectors, but they are concentrated in labour-intensive, low-tech sub-sectors more susceptible to digitalisation. The employment drop between 2011 and 2019 was most significant in occupations with higher digitalisation risk and even more pronounced among women in all regions. Public policies need to be adjusted to the various existing heterogeneities in the global South. It is necessary to explore the synergies between educational, regional, social and science-and-technology policies to balance the impact of new technologies on formal jobs.

JEL codes: J24, J16, R12, O33, L60.

Key words: new technologies; workers; gender; manufacturing; regional inequalities.

Introduction

The impact of digital technologies on the labour market is a question that intrigues many researchers. Previous research emphasised the continued decline in industrial employment and the disappearance of routine jobs (Charles et al., 2013; Davies & van Seventer, 2020). In addition, Autor and Dorn (2013) documented a structural shift in the labour market, with workers relocating their labour supply from middle-wage manufacturing to low-wage service occupations. There has also been substantial employment growth in occupations involving cognitive tasks and problem-solving skills, where skilled labour has a comparative advantage (Acemoglu & Restrepo, 2018a; Autor & Dorn, 2013; Davies & van Seventer, 2020).

The pace of technological change is growing. In the past decades, digital technologies and other technological changes (such as advanced robotics, machines operated by artificial intelligence, machine learning, 3D printing, big data analytics and others involved in the Fourth Industrial Revolution) have transformed the labour market and the skills required by companies. As a result, even in existing occupations, the tasks performed by the workers and the skills needed to perform them have undergone significant changes.

The literature on changes in the labour market related to digital technologies[1] addresses countries in a standardised way, mainly addressing the global North. Despite pointing out that technological adoption depends on each country's previous technological capabilities and productive structure, specific differences between the global South and its heterogeneous regions are not addressed in detail. Some recent studies have started to include some countries from the global South in the debate, although there is still a lack of broad data coverage that allows granular assessment of impacts. We address this gap by bringing empirical evidence about changes in the Brazilian labour market related to occupations with higher and lower digitalisation risk. Brazil is a global South country with 50 million formally employed workers, with substantial regional disparities in economic and social development (Azzoni & Haddad, 2018); it is one of the top fifteen producers of manufactured goods in the world (UNIDO, 2017) and has a well-diversified manufacturing sector (Tessarin et al., 2020a).

[1] We will use *digital technologies*, *digitalisation* and *new technologies* as similar concepts in this article.

As regions within Brazil have distinct productive structures and are at various levels of development, we provide a granular view of the differences among them. Brazil comprises regions with levels of GDP per capita similar to advanced countries such as South Korea and also regions which lag with GDP per capita similar to Pakistan and Nigeria. The distribution of workers, particularly skilled workers, is quite uneven among regions (Galetti, Tessarin & Morceiro, 2021).

The effects of technology adoption are also not gender-neutral, and appear to be more challenging for women. Men make up the largest share of workers – seven out of ten occupations in the Brazilian manufacturing sector are filled by men – although women represent just over half of the country's economically active population. According to the OECD (2018), women spend 2.6 times more time on unpaid care and domestic work than men, leaving less time to invest in their careers and professional training. The proportion of women in technology-related occupations (science, technology, engineering, and maths, or STEM occupations) is much lower than the male share – whether due to personal preference, lack of stimulation[2] or poor access to education geared towards careers that develop maths skills (OECD, 2018). Additionally, women are predominant in manufacturing occupations related to repetitive tasks that can be replaced by new technologies (Brussevich et al., 2018). Thus, women may be more vulnerable than men to adopting new technologies.

This research had two main objectives. In the period 2011 to 2019, on the one hand, there was a rapid spread of digitalisation and adoption of new technologies in factories world-wide, and with that, several occupations became obsolete or more sensitive to replacement; on the other hand, during the same period, the number of manufacturing jobs in Brazil declined. So our first objective was to measure which jobs in the manufacturing sector are more or less susceptible to digitalisation by region, gender and manufacturing sub-sectors. Our second objective was to verify whether the drop in employment between 2011 and 2019 occurred in occupations with a greater or lesser digitalisation risk.

[2] The *ABC of Gender Equality in Education* (OECD, 2015) shows that differences between girls and boys in performance in scientific and ICT-related fields do not stem from differences in aptitudes, but rather from confidence in their own capabilities. Girls are less confident in their maths, science and IT abilities often due to societal and parental biases. This ultimately leads girls to lower engagement in science and ICTs.

The following questions guided this research: Is the digitisation risk greater in more advanced and diversified regions than in lagging regions? Are men proportionately more susceptible to digitisation than women? Are labour-intensive manufacturing sub-sectors more susceptible to digitisation than more capital-intensive ones? Is the recent drop in Brazilian manufacturing employment concentrated in occupations most at risk of digitisation?

We intend to quantify and qualify the transformations in the labour market by approaching the differences with respect to gender, industries and regions from a global-South perspective. Unlike previous research investigating the potential effects of new technologies on the labour market at a country level, we hope to contribute to the debate by providing a more profound analysis detailing intra-regional, sectoral and gender disparities in changes in the labour market. To our knowledge, such differences have not yet been addressed for the global South because it is challenging to find well-disaggregated data across multiple dimensions, although they have consequences for designing inclusive and egalitarian policies. That is why we have made an effort to offer, first, an image of this scenario in descriptive terms.

This work is organised as follows. The next section is a brief review of the literature on the implications of digitalisation on the labour market, regional approaches and gender concerns. In the third section, we present data and methodological procedures. The fourth section presents the results and a discussion based on the evidence found. The last section concludes the study.

Literature review

New technologies are causing changes in the mode of production and the demand for workers (Brynjolfsson & McAfee, 2014; Frey & Osborne, 2017). Technological transformation can induce productivity gains in the long term; however, in the short term, it can intensify replacing workers with machines, generating social tensions due to the increase in unemployment (Charles et al., 2013), as there is no guarantee that new occupations may emerge to quickly compensate the lost jobs (Autor & Dorn, 2013). Many activities that once involved several workers can now be performed by just one person from a distance, using information technologies and robots. At the same time, new technologies can demand new skills, open space for new roles in a current occupation and even create additional jobs (Berger & Frey, 2016).

Part of the literature argues that occupations that involve routine tasks are more likely to be replaced by new technologies because they are performed repetitively and with a low level of improvisation (Acemoglu & Restrepo, 2018b; Autor & Dorn, 2013; Davies & van Seventer, 2020; OECD, 2017), so they are easier to code. However, with the advancement of artificial intelligence and machine learning, even occupations that involve cognitive tasks can be replaced by still more modern technologies (Acemoglu & Autor, 2010). By contrast, occupations that require creativity and problem solving are less susceptible to substitution (for instance, graphic designers, lawyers and tooling technicians), along with occupations which are intensive in manual tasks but do not involve routines (janitors, health aides and quality controllers, for example), since it is more difficult to codify their procedures (Frey & Osborne, 2017; Davies & van Seventer, 2020). Some authors also argue that occupations related to traditional technologies have changed the profile of tasks required (Brynjolfsson & McAfee, 2014; Davies & van Seventer, 2020; OECD, 2017): to adapt to new production techniques, workers in such jobs began to perform additional functions and thus were successful in remaining in the labour market. To illustrate, one can imagine production-line controllers who have upgraded themselves to programming, and control the production via machine learning. And there are still new occupations emerging in recent years that were not relevant decades ago because the equipment and technologies they deal with today did not exist (cybersecurity engineer and 3D printing machine operator, for example). Berger & Frey (2016) present several examples of occupations disappearing, growing or emerging to put new technologies into practice. Therefore, there is still an issue under debate in the literature about the employment balance after adoption of new technologies by industry.

To add complexity to the discussion, it is imperative to specify the context of the country being analysed. There are differences in the processes of adopting new technologies in countries of the global North – that are on the frontier of technological development, develop labour-saving technologies and have medium-high and high technological intensity sub-sectors in an advanced stage of automation – compared to countries of the global South, where employment is concentrated in labour-intensive sub-sectors, and which have a surplus of unemployed labour and typically import machinery and equipment created in the global North (Morceiro & Guilhoto, 2020; Tessarin et al., 2020b). Most countries in the global South have technologically outdated equipment and, in many cases, do not have adequate infrastructure to employ the information and communication technologies (ICT) necessary for the digitalisation of production processes (Lorenz et al., 2019; Ferraz et al., 2020). Finally, the production structure is concentrated on products of lower technological content that involve traditional production processes, as is the case in Brazil (Morceiro, 2018).

Advances in digital technologies, including machine learning algorithms and cloud computing, can substitute for workers in jobs that require routine cognitive tasks in developed nations (Graetz & Michaels, 2018; Sorgner, 2019). However, such technology is still far from mass adoption in the global South. According to Eden and Gaggl (2015), capital stock related to ICT is still low in such countries. Thus, when dealing with technologies related to the Fourth Industrial Revolution (for example, machine learning or artificial intelligence), there is a barrier to internalising them in most companies from countries in the global South (Ferraz et al., 2020), which have not even completed the Third Industrial Revolution (involving the mechanisation of production processes).

In a seminal work, Frey and Osborne (2017) identified the replacement possibility of various occupations based on a workshop held at the Oxford University Engineering Sciences Department to evaluate the probability for automation of a wide range of tasks. The authors showed that 47% of occupations in the current US labour market are susceptible to replacement by new technologies. Several studies based on Frey and Osborne (2017) and mainly focused on the global North sought to identify the percentage of occupations at risk of replacement, in the United States (Arntz et al., 2016), European countries (Berger & Frey, 2016), and G20 economies (Sorgner et al., 2017). These studies indicate that the probability of replacement of workers is high (above 60%) and varied according to the types of industrial sub-sectors in each country. We found few studies focusing on the global South. Among these, Chang and Huynh (2016) analysed five ASEAN countries[3]

[3] This study included Cambodia, Indonesia, Philippines, Thailand and Viet Nam.

and found that about 56% of employment is at high risk of displacement in such countries. Sorgner (2019) compared the impact of automation in eleven countries located in Africa, Asia, South America and Eastern Europe.[4] The average automation risk in those countries was 63%, but results varied considerably among countries according to levels of formal education. The risk of automation for highly educated workers is about half than it is for less educated workers. Adamczyk, Monasterio and Fochezatto (2021) pointed out that about 56% of workers (excluding the public sector) are in occupations with high or medium-high susceptibility to automation in Brazil, and workers with lower educational levels and wages are more susceptible to automation. Albuquerque et al. (2019) also identified a similar percentage (54.5%) for Brazil, qualifying that the occupations analysed were concentrated in activities which were intensive in routine skills and low cognitive levels.

Countries in the global South differ from the global North in terms of the effects of new technologies for several reasons, such as the prior automation level, workforce education level and availability of resources for investment. In addition, the economy's sectoral composition has a significant influence on this matter. The probability of automation differs because some sub-sectors traditionally involve more mechanised production processes than others (Andreoni, 2019; Ferraz et al., 2020; Lorenz et al., 2019); for example, the automotive industry is capital intensive, while the footwear and apparel sub-sectors are labour intensive.

Nevertheless, automation may be feasible from a technological point of view but not economically viable, depending on the industrial structure and level of development (Lorenz et al., 2019). Andreoni (2019) showed that the distribution of industrial robots across productive sectors is quite uneven. For example, the electrical and electronic industry is one of the leading sectors in adopting industrial robots, while textiles, paper and wood and furniture are opposite.

Based on the aforementioned literature and the unique characteristics of the global South, we outline some hypotheses around the unequal aspects of digitalisation in the labour market. Our first hypothesis is that high-tech manufacturing sub-sectors and low-tech labour-intensive sub-sectors are more likely to digitalise

[4] Countries included in this study are Armenia, Bolivia, Colombia, Georgia, Ghana, Kenya, Laos, North Macedonia, Sri Lanka, Ukraine and Viet Nam.

occupations. The former have a high level of automation, which enables assimilating new technologies quickly; the latter still have a significant margin for work replacement. This means that occupations may be more or less susceptible to digitisation depending on the type of tasks needed to perform their functions, which will have implications for gender and other forms of inequalities.

Additionally, there are solid reasons to take account of intra-regional differences within countries, given the regional allocation of the productive structure and the technological development level of each region's sub-sectors. Further to the level of automation being different amongst industries, some regions lag behind others, and consequently, the same industry may have adopted technology to different levels in different locations (Lorenz et al., 2019), especially in a country such as Brazil which is so unequal regionally. The decision to locate an industry still involves questions of state or local subsidies. Governments that aim, for example, to attract modern and less polluting industries, or labour-intensive industries (to help reduce local unemployment), or industries related to regional specialisation (to reinforce productive clusters) use subsidies to influence companies' decisions, and this element determines the geographical distribution of manufacturing.

Brazil has continental dimensions and geographic heterogeneity that implies high transport costs to connect all regions. Besides being territorially a large country, it has deep regional disparities in income, population, education, access to public services and innovation systems (Azzoni & Haddad, 2018; Galetti et al., 2021). Furthermore, Brazil is amongst the countries with the highest inequality index globally, measured by the Gini index (Reis, 2014)[5]. However Brazil's productive structure is very diverse for a global South country, as it is in the top fifteen in the world in almost all manufacturing sub-sectors (Morceiro, 2018; UNIDO, 2017). Brazil also has a robust agro-industrial sector in the country's central area and a mature service sector in the South and Southeast regions, the most advanced regions. A large part of the gross domestic product (GDP) is produced in the country's south-south-eastern axis, which also sustains the most diversified productive structure – manufacturing and services – and attracts more qualified workers, in contrast to the northern and north-eastern regions, which have less diversified economies and less technological content (Galetti et al., 2021). Furthermore,

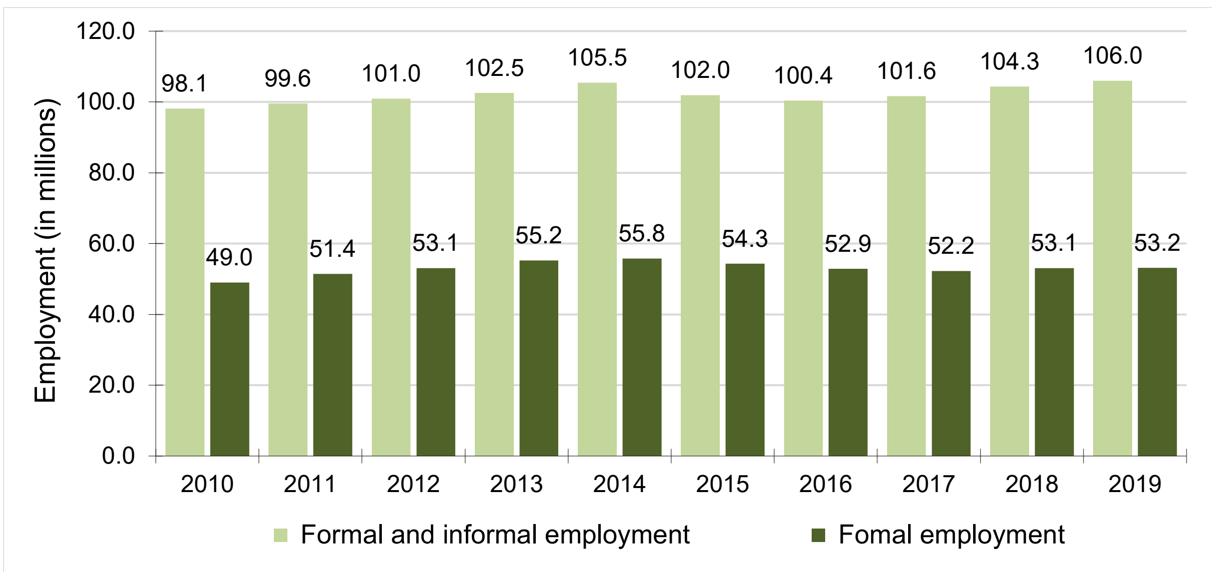
[5] Reis (2014) explains in detail the geographic, historical and social roots of income inequality in Brazil.

the regional concentration of top skills in a few regions has been very persistent over the decades (Ehrl & Monasterio, 2019).

In this context, our second hypothesis is that advanced regions are more likely to have occupations at higher risk of digitalisation than lagging regions, since the pace of new technology adoption differs greatly between them.

After two decades of low growth, Brazil grew at a rate similar to world GDP from 2003 to 2014. During this period, the volume of total employment (formal and informal) increased from 84 million to 104.5 million (or 2.1% a year), and formal employment increased from 34.1 million to 55.8 million (or 4.6% per year) – that is, the increase in employment came mostly from increases in formal occupations. However, the country entered a political-institutional crisis in 2015/16, resulting in the impeachment of President Dilma Rousseff in 2016. In 2015 and 2016, there was a decline in employment, which fully recovered between 2017 and 2019 (see Figure 1).

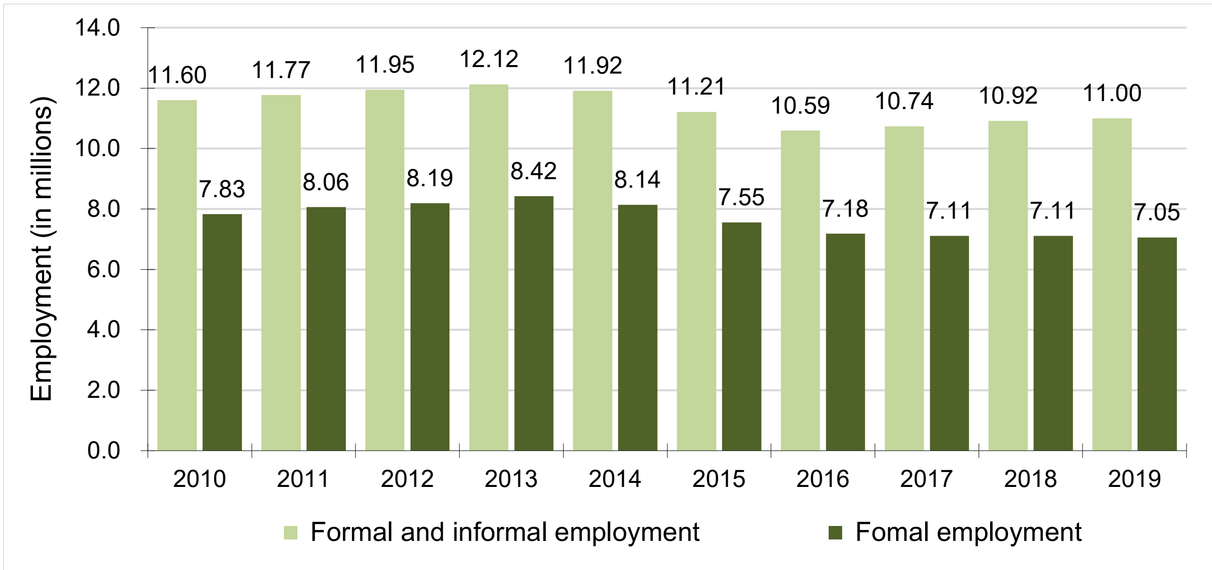
Figure 1: Formal and informal employment in the Brazilian economy, 2010-2019



Source: National Accounts System of Brazil.

However, the scenario for the manufacturing sector was different. The level of formal employment began to shrink in 2014 and continued to fall until 2019, with no recovery (Figure 2).

Figure 2: Formal and informal employment in Brazil's manufacturing sector, 2010-2019



Source: National Accounts System of Brazil.

It is tough to specify the share of formal manufacturing jobs lost due to technological updates and the consequent replacement of workers by modern machines. With the emergence of new technologies to increase productivity and reduce costs, jobs may have been replaced by smart machines. Besides, part of the job loss in the manufacturing sector is also due to internal strains (low international competitiveness and political-economic crisis in Brazil) that have limited economic growth since the middle of the second decade of the 21st century.

The impact of new technologies can also differ by gender. We know inequality in the labour market is harmful to women. For example, women receive lower wages for identical occupations filled by men (Haussmann & Golgher, 2016). According to Sorgner (2019), new technologies reinforce the gender gap significantly in the labour market because women mostly occupy positions unrelated to STEM occupations. It means that opportunities may not be fully accessible to women because they lack the skills necessary for such occupations which, indeed, are more associated with the new technologies. Additionally, in manufacturing, women are predominantly in occupations related to repetitive tasks that can be replaced by new technologies (Brussevich et al., 2018).

Mariscal et al. (2019) noticed a significant digital gender divide: lower access to and use of digital technologies by women than men, particularly in less developed countries. For them, this is a result of poor education and unfavourable work conditions for women (Mariscal et al., 2019; Sorgner, 2019) and may imply that women are vulnerable in the labour market as this is likely to limit their employment prospects in jobs that depend on the use of such technologies.

Brussevich et al. (2018) analysed the female workforce in OECD countries. They found that, generally, women are more likely to perform routine tasks that can be replaced by machines and are also less involved in analytical tasks that machines can supplement. They also identified that less educated and older female workers are more susceptible to being replaced by new technologies. Sorgner et al. (2017) found that the risk of replacement decreases as the level of education increases for both men and women in a set of OECD countries. However, they also found that women with less education are less likely to lose their jobs (as opposed to men), probably because they are in occupations that, although low-skilled, require more non-routine manual skills that are difficult to automate.

In addition to the risk of replacement, women also face greater challenges with regard to professional relocation. According to Madgavkar et al. (2019), women will need to make much more significant transitions compared to men, often into higher-skilled roles, and may find it more difficult to capture new opportunities because of the persistent barriers they face. The negative impact on women could be more severe because of the barriers to access the labour market, ranging from the field of formal education (human sciences instead of engineering) to the type of skills and tasks they handle and the availability for re-skilling given the time devoted to unpaid work. Thus, if they lose their jobs, the chances of replacement are even rarer.

Thus our third hypothesis is that men are more likely than women to be in occupations with a high risk of digitisation. The differing task content of jobs and the risks attached to them may lead to high or low risk of displacement by technology. Jobs with a higher share of tasks that can be easily codified are more susceptible to automation. In absolute terms, men form the largest share of the workforce and are therefore numerically at greater risk. Additionally, men predominate in physical occupations – such as machine operators and craftworkers – that could be displaced by digitalization. Conversely, women predominate in occupations that require cognitive work and non-routine tasks, such as clerical support or personal assistance (in addition to aid and health care, which is not a manufacturing sector).

Due to so many peculiar characteristics of the impact of new technologies on the Global South labour market, we propose a comprehensive assessment of Brazil's manufacturing sector by regions, sub-sectors and gender in terms of greater or lesser risk of digitalisation. We understand that technological readiness, the structural composition, and the distribution of men and women in occupations in each region help to elucidate the complex puzzle about changes in the labour market. The following sections address this issue.

Data and methodological approach

To carry out this research, we prospected countries within the global South that have datasets which are well-disaggregated at the level of occupation, gender, sub-sectors and regions. We chose Brazil because it has a comprehensive open database called RAIS (in English, Annual Social Security Information Report) compiled by the Labour Secretary of Brazil. RAIS provides information about 50 million formally employed workers,[6] has a long time series (from 2003 to 2019) and is disaggregated to the level of occupations (nearly 2500 in total), industrial sub-sectors (up to 600 in the most disaggregated classification) and regions. This database allowed us to combine the variables in different aggregations by gender, manufacturing industries and regions, enabling this study.

To assess recent changes in the labour market, we chose the period from 2011 to 2019. The 2007/8 international financial crisis hit the Brazilian economy at the end of 2008 and 2009. Still, the country quickly recovered in 2010, so we selected 2011 as the initial year because the effects of the crisis did not influence it. The latest year available at the time the data was collected was 2019.[7] We will begin the characterization of the

[6] RAIS covers practically all formal occupations. In 2018, 50.9% of the employment in Brazil was formal, a percentage that increases to two thirds in the manufacturing sector (Nassif & Morceiro, 2021).
[7] We also decided not to include the first decade of the 21st century because the digitalisation of manufacturing in the Global South is a more recent phenomenon.

Brazilian manufacturing labour market with data from 2011 considered from different perspectives, and then we will present how it evolved until 2019.

Identification of occupations with the highest and lowest risk of digitalisation

Like other authors (Adamczyk et al., 2021; Albuquerque et al., 2019; Arntz et al., 2016; Berger & Frey, 2016; Chang & Huynh, 2016; Sorgner, 2019;), we draw on the seminal article by Frey and Osborne (2017) to select occupations with the highest and lowest risk of digitalisation. Frey and Osborne (2017) classified 702 detailed occupations at the six-digit level according to their probability of computerisation. Such authors identified the possibility of replacement of occupations in a workshop held at the Oxford University Engineering Sciences Department to evaluate the "automatability" probability of a wide range of tasks. Experts examined automatability based on the task and job descriptions of each occupation (available on the O-NET list). This information is particular to each occupation, regardless of where the employee works. Automatibility was evaluated by answering the question "Can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by the state of the art computer-controlled equipment?" Thus, we understand that the probability of automation is not linked to the profile of the labour market in a specific country, so it can be replicated in other contexts.

We created a correspondence table for the occupation list provided by Frey and Osborne (2017) and the Brazilian occupation list (named CBO, Classificação Brasileira de Ocupações) to identify the occupations most and least susceptible to substitution by the digital technologies. We then divided the occupations into two groups:

a) higher digitalisation risk: includes occupations with a probability of computerisation equal to or greater than 75%. This group has 806 Brazilian occupations, equivalent to 32.5% of all occupations;

b) lower digitalisation risk: includes occupations with a probability of computerisation below 75%. This group comprises 1672 Brazilian occupations, representing 67.5% of the total.

The Frey and Osborne methodology was developed through an expert survey carried out at the University of Oxford to assess the risk of each occupation being run by a machine. It does not take into account the quality of training for workers or the technological level of the factory. That is why this methodology can be widely replicated in many countries.

We analysed the number of jobs by digitalisation risk[8] across different breakdowns with regard to regions, tech groups, industries, and gender.

Regional breakdown, tech groups, manufacturing industries and gender

Due to the Brazilian continental dimension and the remarkable regional heterogeneities already highlighted, we worked with five macro-regions: South, Southeast, Midwest, Northeast and North (see Appendix B for information on population and GDP per capita for each region)[9]. The South and Southeast regions are the most industrialised and diversified, with the highest Human Development Index, compared to the most backward North and Northeast regions; the Midwest region concentrates modern agroindustry, which has experienced robust expansion over the last two decades.

To capture details by sub-sector and technology groups, we worked with 23 manufacturing industries on the two-digit breakdown of ISIC 3.1 (International Standard Industrial Classification), as shown in Table 1. We followed the UNIDO classification (UNIDO, 2010), which groups the manufacturing sub-sectors into three technology groups, arranged in Table 1.

We also worked with gender at the level of Brazil, the macro-region, technological groups and manufacturing industries, and we cross-tabulated all this information at the most detailed level of analysis in the fourth section.

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[8] We will use the terms high risk or higher risk interchangeably.

[9] Brazil comprises 5568 municipalities grouped into 27 federation units – an administrative unit similar to a province – which are organized into five macro-regions. Municipalities, as well as federation units, have autonomy and local decision-making powers.

Table 1: Manufacturing industries by technological intensity

Manufacturing sub-sectors (ISIC 3.1)	Short names	Industries by tech intensity	Short names
Food products and beverages	Food	Low-tech	Low tech
Tobacco products	Tobacco		
Textiles	Textiles		
Wearing apparel; dressing and dyeing of fur	Apparel		
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	Leather		
Wood and wood products	Wood		
Paper and paper products	Paper		
Publishing, printing and reproduction of recorded media	Printing		
Furniture; manufacturing n.e.c.	Furniture and other		
Recycling	Recycling		
Coke, refined petroleum products, nuclear fuel and alcohol	Refined petroleum	Medium-low tech	Medium tech
Rubber and plastics products	Rubber and plastic		
Other non-metallic mineral products	Non-metallic		
Basic metals	Basic metals		
Fabricated metal products, except machinery and equipment	Fabricated metal		
Chemicals and chemical products	Chemicals	Medium-high and high tech	High tech
Machinery and equipment n.e.c	Machinery		
Office, accounting and computing machinery	Computers		
Electrical machinery and apparatus n.e.c	Electrical equipment		
Radio, television and communication equipment and apparatus	Radio, TV, communication		
Medical, precision and optical instruments	Medical instruments		
Motor vehicles, trailers and semi-trailers	Vehicles		
Other transport equipment	Transport equipment		

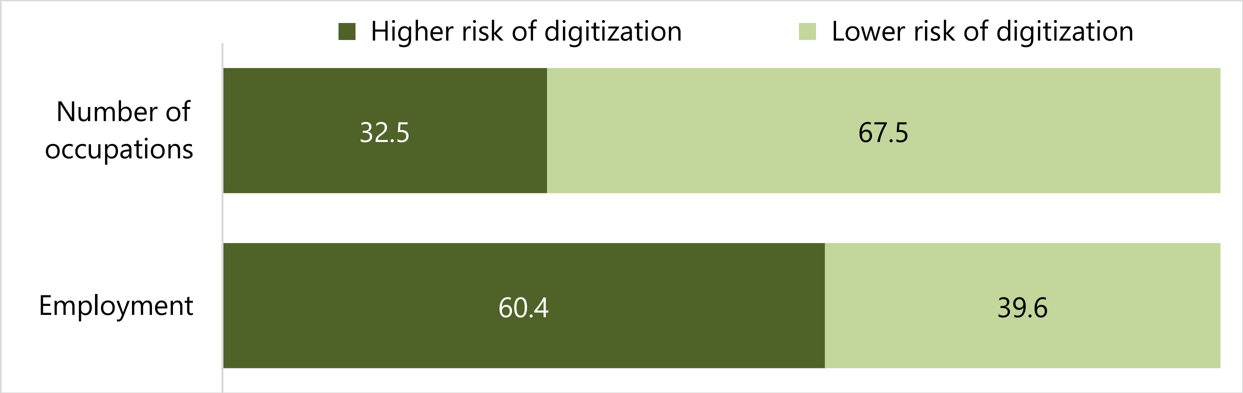
Source: UNIDO (2010). Note: n.e.c. means not elsewhere classified.

Worker digitalisation risk in the Brazilian manufacturing industry

On one hand, the number of occupations classified as having the highest risk of digitalisation corresponds to 32.5% of the current occupations in the Brazilian manufacturing sector. However, it represents 60.4% of the jobs generated in 2019 (Figure 3). On the other hand, occupations classified as having the lowest risk of automation correspond to 67.5% of the occupations and represent 39.6% of employment. In other words, six out of ten manufacturing jobs, distributed across three out of ten existing occupations, have a high probability of being replaced by equipment that incorporates new technologies.

The probability is probably overestimated for the global South, since actual replacement depends on various factors such as investment in modern capital goods, physical infrastructure that enables the adoption of information technologies in the productive stages (such as internet signal coverage and a high-speed network), technical viability of adjusting modern technologies to current factories and infrastructure, and competitiveness, so that the return on investment is compensated, among other factors. It should be noted that in the global North, there are incentives to increase the automation of industrial processes because there is relatively more expensive and less abundant labour than in countries of the global South, such as Brazil.

Figure 3: Share of occupations and manufacturing employment by digitalisation risk in Brazil (2019)



Source: Data from Labour Secretary of Brazil.

Table 2 displays the 50 occupations that employ most workers in the manufacturing sector and the risk of digitalisation for each occupation. Together, the 50 occupations concentrated 53.1% of manufacturing jobs in 2019. The first occupation, assembling labourers, which is classified as being at high risk of digitalisation, concentrates the largest number of workers (11.56% of total manufacturing jobs).

Table 2: Top 50 occupations by employment in Brazilian manufacturing by digitalisation risk (2019)

Rank	Occupation name	Digitalisation risk	Manufacturing employment	Share in manufacturing employment (%)
1	Assembling labourers	Higher	801 600	11.56
2	General office assistant	Lower	182 164	2.63
3	Secretaries and administrative assistant	Lower	149 612	2.16
4	Sewing machine operators, manual	Higher	126 100	1.82
5	Plant operators	Higher	123 662	1.78
6	Heavy and tractor-trailer truck drivers	Lower	119 913	1.73
7	Industrial machinery mechanics and repairers	Higher	112 160	1.62
8	Stock clerks	Higher	107 692	1.55
9	Sewing machine operators	Higher	102 596	1.48
10	Related food preparers	Higher	100 206	1.45
11	Welders and flame-cutters	Higher	99 520	1.44
12	Agricultural managers	Lower	93 179	1.34
13	Janitors and cleaners	Lower	92 762	1.34
14	Safety and health inspectors	Higher	83 804	1.21
15	Retail salespersons	Lower	83 176	1.20
16	Shoe machine operators and tenders	Lower	80 005	1.15
17	Machine-tool operators	Higher	74 882	1.08
18	Lifting truck operators	Higher	62 281	0.90
19	Other machine operators	Higher	54 838	0.79
20	Cabinet-makers	Higher	48 337	0.70
21	Production clerks	Higher	45 156	0.65
22	Production and planning technician	Lower	43 657	0.63
23	General and operations managers	Lower	41 909	0.60
24	Electrical mechanics and fitters	Higher	39 906	0.58
25	Butchers	Higher	39 732	0.57
26	Chemical equipment operators and tenders	Lower	38 227	0.55
27	Engine and other machine assemblers	Lower	38 188	0.55
28	Machine tool setters and setter-operators	Higher	37 467	0.54
29	Textile, leather and related cutters	Higher	37 191	0.54
30	Plastic products machine operators	Higher	37 109	0.54
31	Advertising sales agents	Lower	36 343	0.52
32	Sheet-metal workers	Higher	34 334	0.50
33	Quality inspectors	Higher	34 182	0.49
34	Shoemaking and related machine operators	Lower	32 953	0.48
35	Motorised farm and forestry plant operators	Higher	32 334	0.47
36	Office and administrative supervisors	Lower	31 392	0.45
37	Administrative services managers	Lower	30 044	0.43
38	Meat preparers	Higher	28 938	0.42
39	Building construction labourers	Higher	28 318	0.41
40	Assemblers	Higher	28 227	0.41
41	Drivers assistant	Lower	28 134	0.41
42	Food preparation workers	Lower	28 027	0.40
43	Accountants	Higher	27 970	0.40
44	Fibre preparing and winding machine operators	Higher	27 560	0.40
45	Sales representatives wholesale and manufacturing	Lower	26 635	0.38
46	Stock clerks	Higher	26 487	0.38
47	Bricks tiles and abrasive wheels workers makers	Higher	26 441	0.38
48	Structural-metal preparers and erectors	Higher	26 211	0.38
49	Office clerks general	Lower	25 997	0.38
50	Pottery and porcelain workers makers	Higher	25 834	0.37
	Subtotal		3 683 392	53.1

Source: Data from Labour Secretary of Brazil.

Of the top ten occupations in Table 2, seven are more susceptible to new technologies, representing 21.3% of manufacturing employment (1.474 million workers). Occupations with the highest risk of digitalisation include, in addition to assembling labourers, sewing machine operator, plant operator, industrial machinery mechanic and repairer and stock clerk. Occupations such as general office assistant, secretary and administrative assistant, and truck driver are the three among the top ten with the lowest digitalisation risk (they employ 6.5% of manufacturing workers). These three occupations involve non-routine tasks and require critical thinking and decision making – skills that cannot be easily codified and replicated. Hence, there is still a limited range of new technologies.

There are 806 manufacturing occupations classified as being at high risk of digitalisation, which concentrated 60% of manufacturing jobs in Brazil in 2019. However, only 107 of the 806 occupations concentrate 83% of jobs at risk of digitalisation (or 50% of manufacturing jobs). It is such a narrow group that policymakers should monitor and assist it.

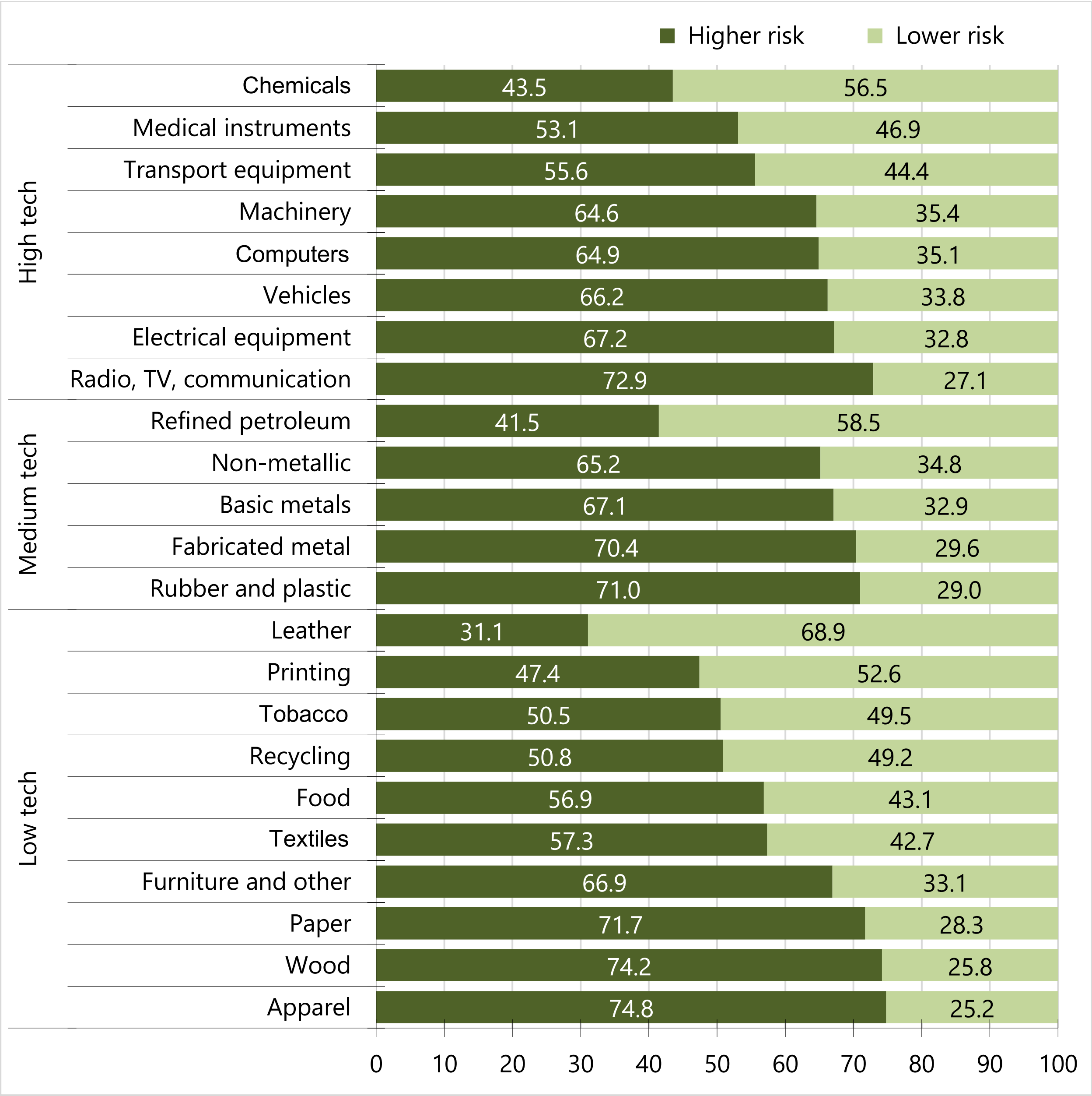
Contrary to what one might think, not all low-skilled occupations tend to be replaced by new technologies. Indeed, the task content required defines which occupations can have their activities codified and performed by equipment that adopts new technologies (Acemoglu & Autor, 2010). For example, forklift truck operators and 'other machine operators' (packers) (positions 18 and 19 on Table 2) are occupations that involve routine and codable tasks. The adoption of robots and smart sensors can be used to perform such functions. Although cleaners (position 13) and sales agents (position 31) involve low skills compared to other high-skilled occupations, they also require social skills and personal interaction, which are hardly reproduced by new technologies. Studies show that social skills are still among the most difficult to code for robots (Autor et al., 2003; OECD, 2017); thus, functions that involve personal contact and care require the human component to be performed successfully.

Digitalisation risk: a view of industries

To understand the dimensions of the effects of digitalisation on the Brazilian labour market, it is also necessary to know the distribution of manufacturing sub-sectors, given that some sectors are more labour intensive while others are technology intensive.

Figure 4 shows the employment share in manufacturing sub-sectors by digitalisation risk in 2011, the initial year of this study. As explained previously, we grouped the sub-sectors by technological intensity – low, medium and high technology – according to UNIDO (2010). Although there is substantial sub-sectoral heterogeneity regarding the risk of digitalisation, almost all sub-sectors – except chemical, refined petroleum, leather and printing – had more than 50% of jobs at high risk of digitalisation.

Figure 4: Share of total employment in Brazil's manufacturing sub-sectors by digitalisation risk (2011)



Source: Data from Labour Secretary of Brazil.

The low-tech group mainly includes labour-intensive manufacturing sub-sectors, usually relevant in the global South and backward regions. In three sub-sectors of this group – paper, wood and apparel – more than 70% of occupations were at a high risk of automation (Figure 4). In the medium-tech group, metal products and plastics also showed more than 70% of jobs at high risk of digitalisation. By contrast, only one sub-sector in the high-tech group stated a similar percentage (radio, TV and communication). It should be noted that this last sub-sector predominantly carries out assembly activities in Brazil – similar to the Mexican maquiladoras – and does little industrial transformation (Morceiro, 2018). Hereby, our hypothesis about sub-sectoral inequality has been confirmed: labour-intensive, low-tech sub-sectors show a higher percentage of employment at a high risk of digitisation, as do high-tech sub-sectors that show a faster rate of technological change.

As mentioned, the unequal share of jobs with greater or lower risk of digitalisation is related to the techno-productive characteristics of the sub-sectors and regions (Andreoni, 2019; Lorenz et al., 2019; Sorgner et al., 2017). In some cases, such as refining petroleum, a very capital-intensive sector, the capital-labour ratio is already at its limit – that is, most occupations interact with frontier technologies and there is no room for further modernization or for replacing jobs with digital technologies. However, this is not the reality in the clothing or furniture sub-sectors, which still rely heavily on occupations that demand repetitive and easily encoded tasks; therefore, there is plenty of room for introducing new technologies to perform the same human job.

In summary, there is heterogeneity among the manufacturing sub-sectors in Brazil regarding the risk of digitalisation, even within the same technological group, as shown in Figure 4.

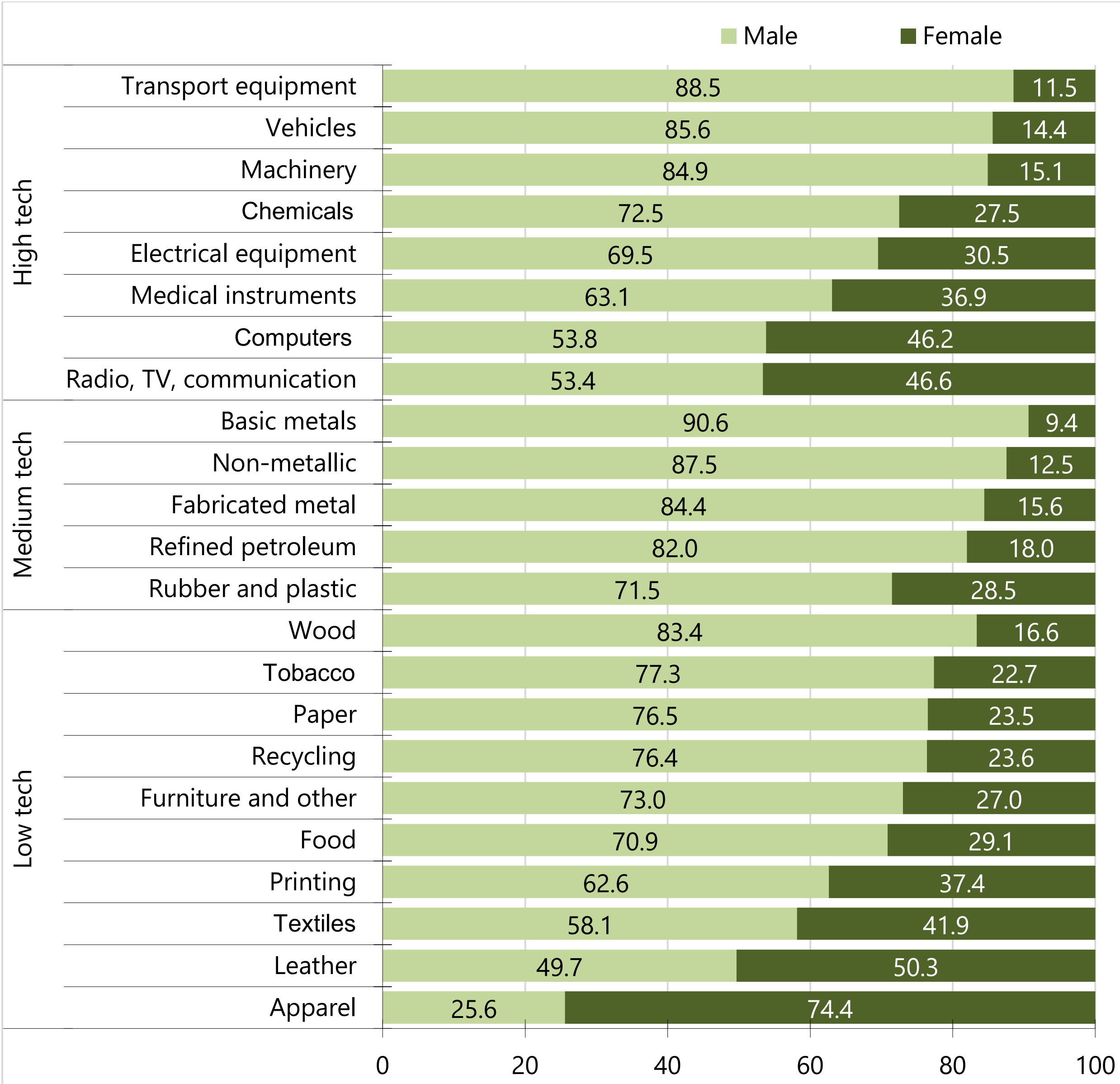
Digitalisation risk: a gender and sub-sector view

Worldwide, sub-sectors that require manual dexterity employ more women and occupations that require greater physical strength are occupied mainly by men (Mariscal et al., 2019; Sorgner, 2019). However, little by little, we see changes, including the advent of new technologies that allow workers, regardless of gender, to perform identical functions with similar productivity.

Figures 5 to 7 show the distribution of employment by gender. In most manufacturing sub-sectors, male workers are the majority – except in apparel and leather (Figure 5) – and they represent more than seven out of ten jobs in two-thirds of the sub-sectors.

The low proportion of female workers in capital-intensive sub-sectors (that is, sectors that employ extensive use of capital goods in the production process in proportion to the number of workers), such as vehicles, transport equipment, machinery segments, chemical segments, basic metals, non-metallic, refined petroleum, tobacco and paper, is an indication that the female share may be at greater risk of losing their jobs in less capital intensive sub-sectors in the case of modernisation and adoption of new technologies in the factories where they work.

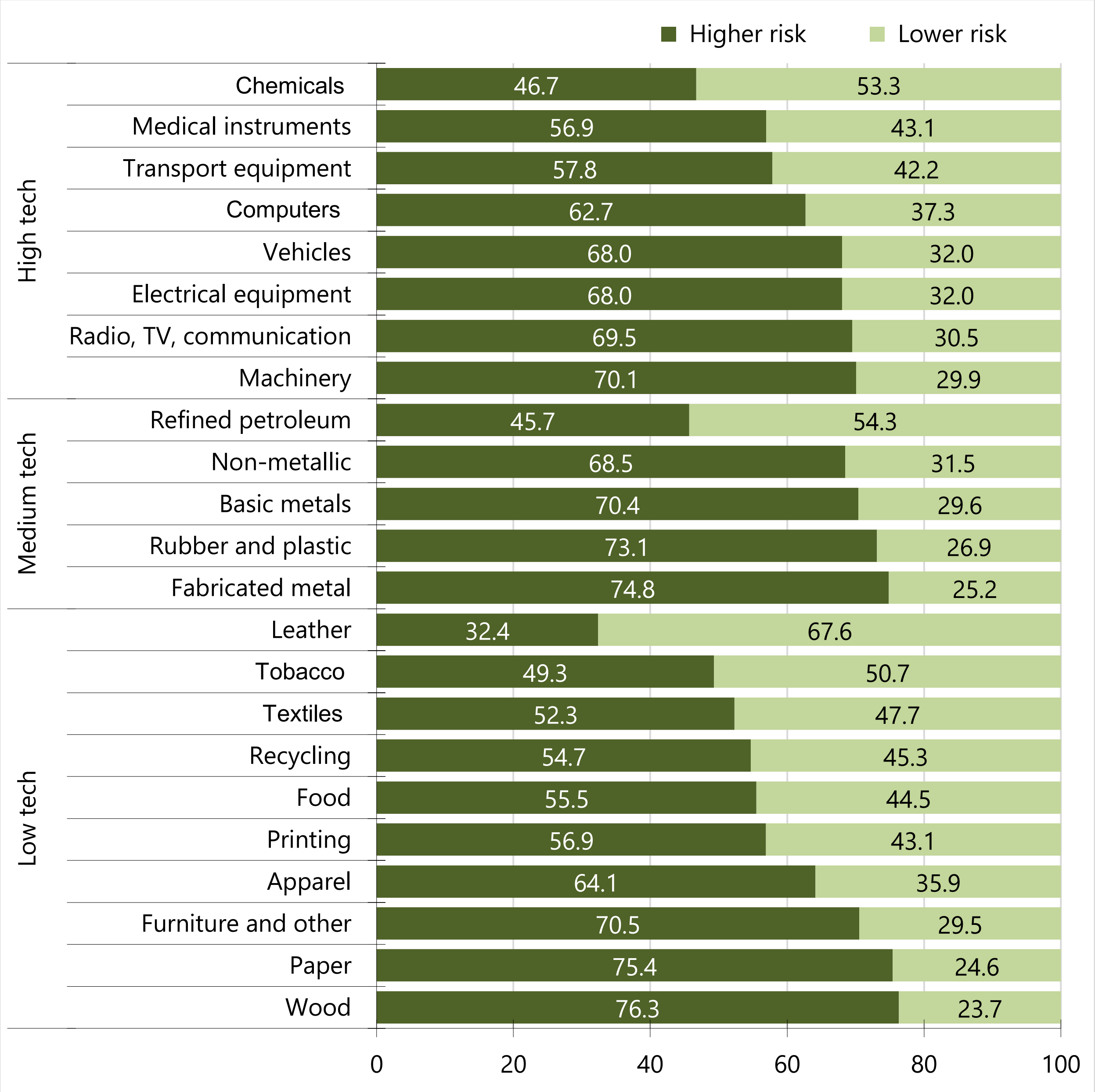
Figure 5: Distribution of employment in Brazil's manufacturing sub-sectors by gender in 2011



Source: Data from Labour Secretary of Brazil.

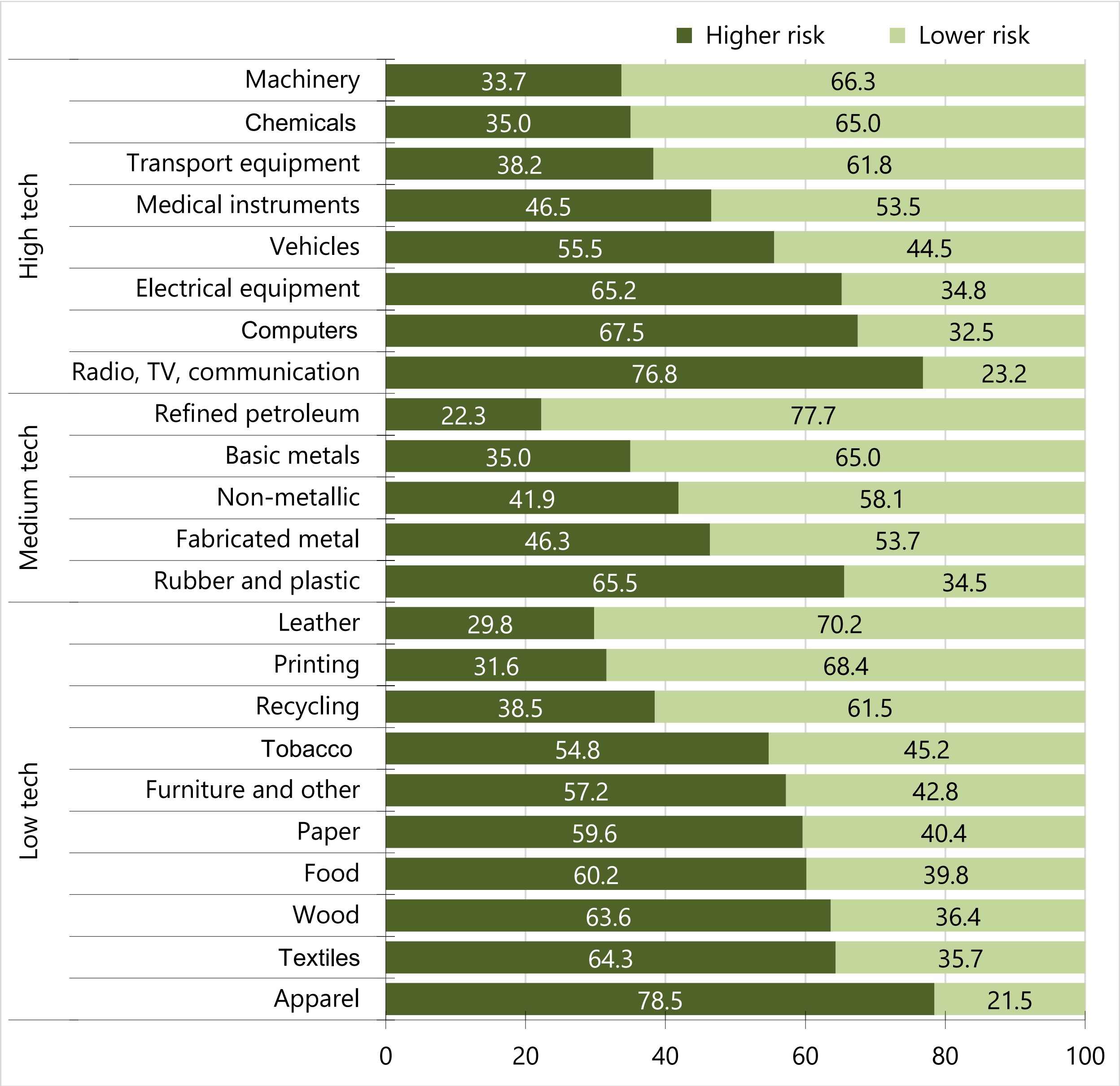
Out of every ten manufacturing jobs, seven are occupied by men and three by women. Nevertheless, does the digitalisation risk by gender also vary widely across sub-sectors? The following figures show the ratio of digitalisation risk (high and low) for occupations filled by men (Figure 6) and women (Figure 7) in each subsector.

Figure 6: Digitalisation risk in Brazil's manufacturing sub-sector employment for men (% - 2011)



Source: Data from Labour Secretary of Brazil.

Figure 7: Digitalisation risk in Brazil's manufacturing sub-sector employment for women (% - 2011)



Source: Data from Labour Secretary of Brazil.

Some differences call our attention. First, men are more at risk of digitalisation than women in most sub-sectors in percentage terms. Even in sub-sectors where the male share is relatively lower (Figure 5), the most significant digitalisation risk is high, as with computers, textiles, and radio, TV and communication (Figure 6). Second, men are more evenly distributed in terms of greater or lower risk of digitalisation, while the women's portion shows greater inter-sub-sectoral variability. Third, in the high-tech sub-sectors with the highest female participation (Figure 5) – radio, TV and communication, computers, medical instruments, and electrical equipment – the digitalisation risk is relatively higher (Figure 7), as well as in low-tech sub-sectors – especially, food, textiles and apparel – which are responsible for more than a third of total Brazilian manufacturing jobs.

In summary, most jobs in almost all manufacturing sub-sectors are male-dominated. In a few labour-intensive sub-sectors women have relatively greater participation. However, in jobs where women are predominant, there is also a high risk of digitalisation.

Regional inequalities

Regional employment distribution pattern

Differences in labour allocation by industry and gender already give us a picture of the effects of the introduction of new technologies in Brazilian manufacturing. Overall, we have previously shown that some sub-sectors employ more occupations with a greater risk of being replaced by new technologies. The distribution of digitalisation likelihood by gender of workers is far from homogeneous. Now we intend to shed light on deep regional inequalities. Some studies recognise that economic and social inequalities lead to different digitalisation performance in the global North and South (Andreoni, 2019; Brussevich et al., 2018; Lorenz et al., 2019; Mariscal et al., 2019), since the pace of new technology adoption differs greatly between them, especially in the more technological sub-sectors. We aim to show that such disparities can also be strong within a country because, in the same way, inequalities in social, physical and technological infrastructure, institutions, economic incentives and even geography lead companies to settle in various locations and adopt new technologies at different rates. We expect the job digitalisation risk to be greater in the more advanced and diversified regions than in the backward regions. Therefore, empirical data that differentiates regions within a global South country which is spatially unequal, as Brazil is, allow us to assess this issue in greater detail.

The lagging North and Northeast regions have half of the GDP per person of the South and Southeast regions (Appendix B.1), which are technologically advanced and diversified. The Northeast region is the second most populous in the country, behind only the Southeast (Appendix B.2). The GDP per person of the Midwest region, the least populous in the country, is currently similar to the advanced regions due to the robust performance over the last two decades of agroindustry for export.[10] Several authors have explored in depth the North/Northeast versus South/Southeast regional inequalities in terms of per capita income (Bucciferro & Ferreira de Souza, 2020), education (Kang et al., 2021), economic development (Reis, 2014) and other perspectives (Azzoni & Haddad, 2018).

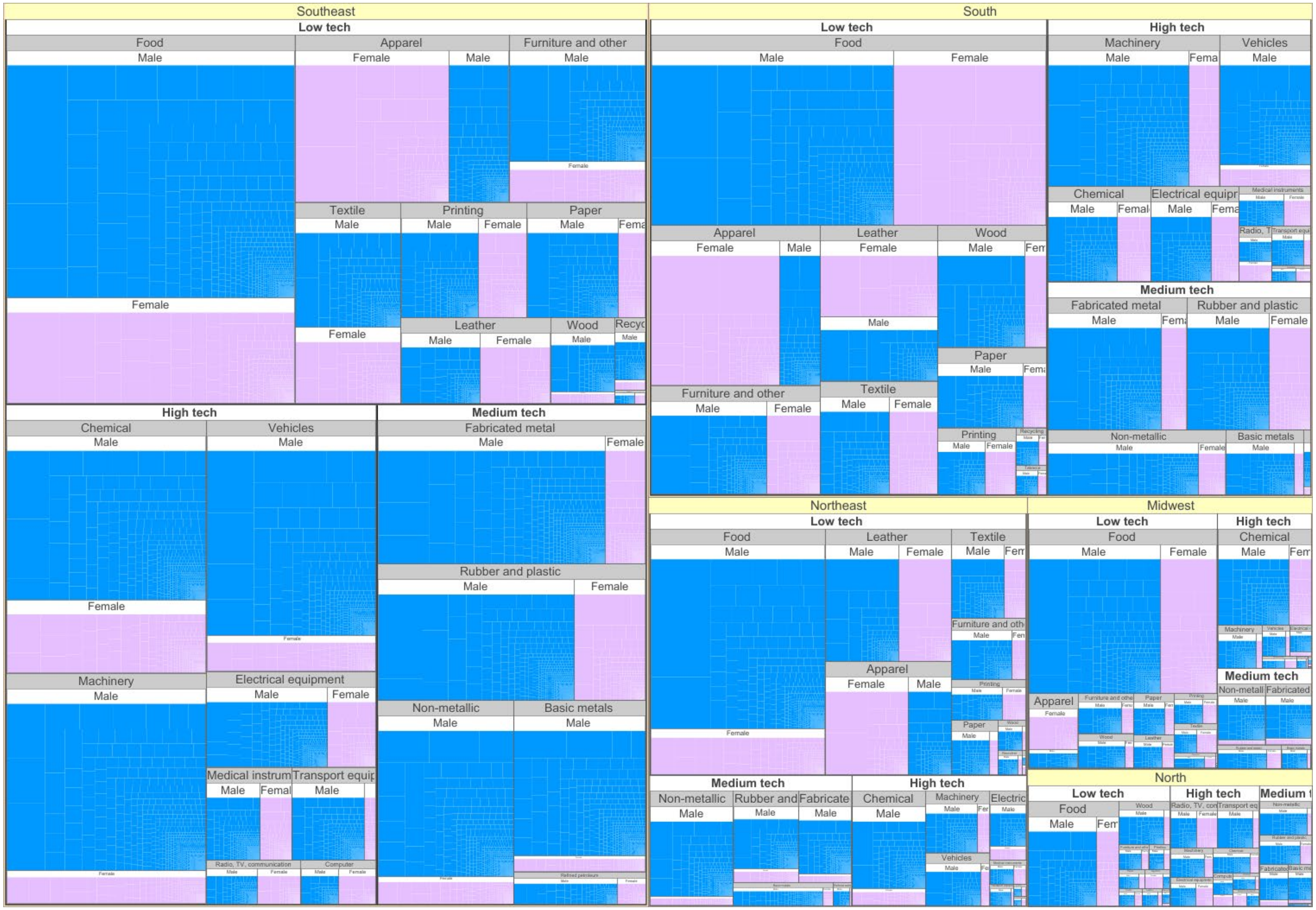
Such regional inequalities are also significant in the distribution of manufacturing jobs by technology group, sub-sector and gender, as shown in Figure 8. The Southeast region (left half of Figure 8) currently concentrates 49.3% of manufacturing jobs in Brazil, followed by the South region (upper right side) with 27.7%, Northeast (lower right side) with 13.1%, Midwest with 6.6% and North with 3.3%. In other words, the South and Southeast regions concentrate 77.0% of manufacturing jobs against 16.4% in the North and Northeast regions, demonstrating the pronounced regional duality. This duality is even more accentuated in sectoral diversification, especially regarding the high-tech sub-sectors, which are much more present in the Southeast and South regions than in the other regions. Note that jobs in the Midwest region are concentrated in the food and chemicals sub-sectors, whose dynamics are linked to export agriculture.

In all five Brazilian regions, the low-tech sub-sectors make up the largest technological group, and the food sub-sector is the one that generates the most jobs of all of them (see Figure 8) – Brazil is a populous country and one of the largest food exporters in the world.

Figure 8 shows some regional nuances: for example, the South has a higher proportion of women workers than the other regions due to low-tech sub-sectors, such as apparel and leather, which generate more jobs for women than men. There are also contrasts by technology group, as the medium- and high-tech sub-sectors gather many more men workers than the low-tech group, which employs relatively more women.

[10] Remember that we are not calculating occupations in agriculture or services, only in manufacturing industries.

Figure 8: Distribution of Brazil's manufacturing employment by region, technology level, sub-sector and gender (2019)



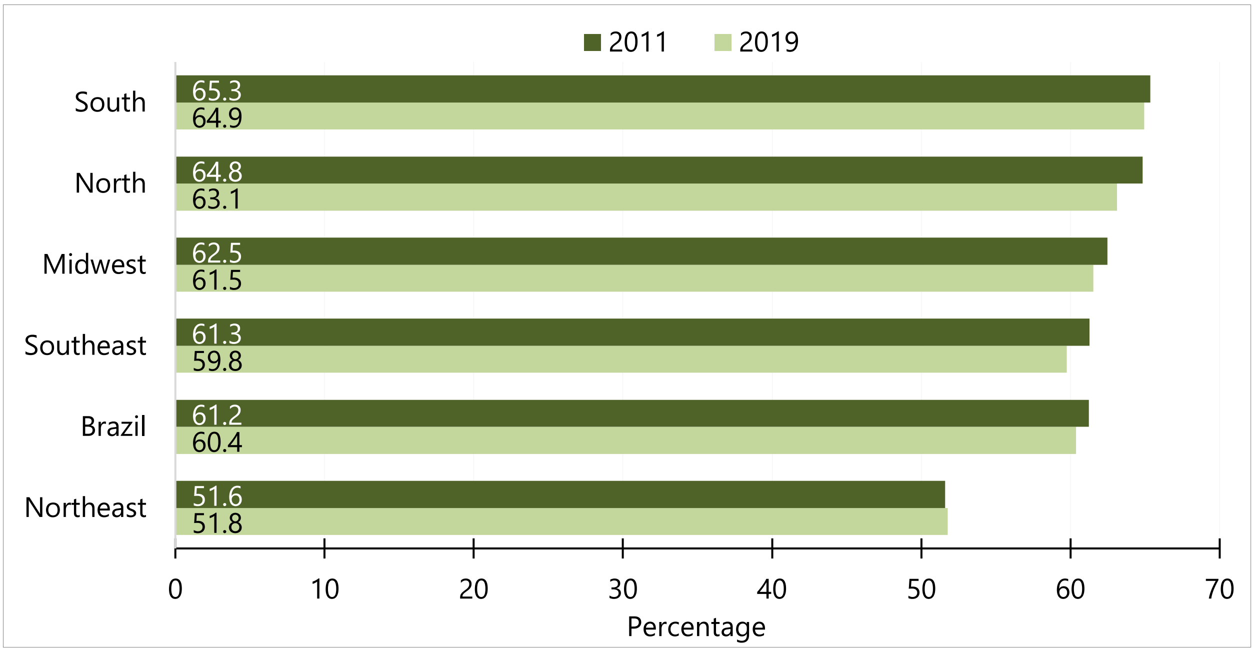
Source: Data from Labour Secretary of Brazil. Note: blue indicates the share of men workers and pink the share of women.

Digitalisation risk by Brazilian regions

This section addresses manufacturing employment in the regions by the degree of digitalisation risk and by gender. Figure 9 shows that there were no significant variations in the distribution of jobs at high risk of digitalisation between 2011 and 2019. One of the reasons we suggest is that the process of modernizing factories to replace human labour is still slow, but evidently undeniable.

In the Northeast region, one of the least developed, the proportion of jobs with higher and lower digitalisation risk is similar. A slightly higher percentage of employment in other regions, around 60%, is at high risk of digitalisation. Comparatively, the level found for the Northeast region is noticeably lower than that found for other global South countries (which reached values closer to 60%). These results confirm the hypothesis that the regions differ: the most backward have a lower risk of digitalisation than the more advanced regions, except for the North.[11]

Figure 9: Share of manufacturing employment with higher digitalisation risk by region

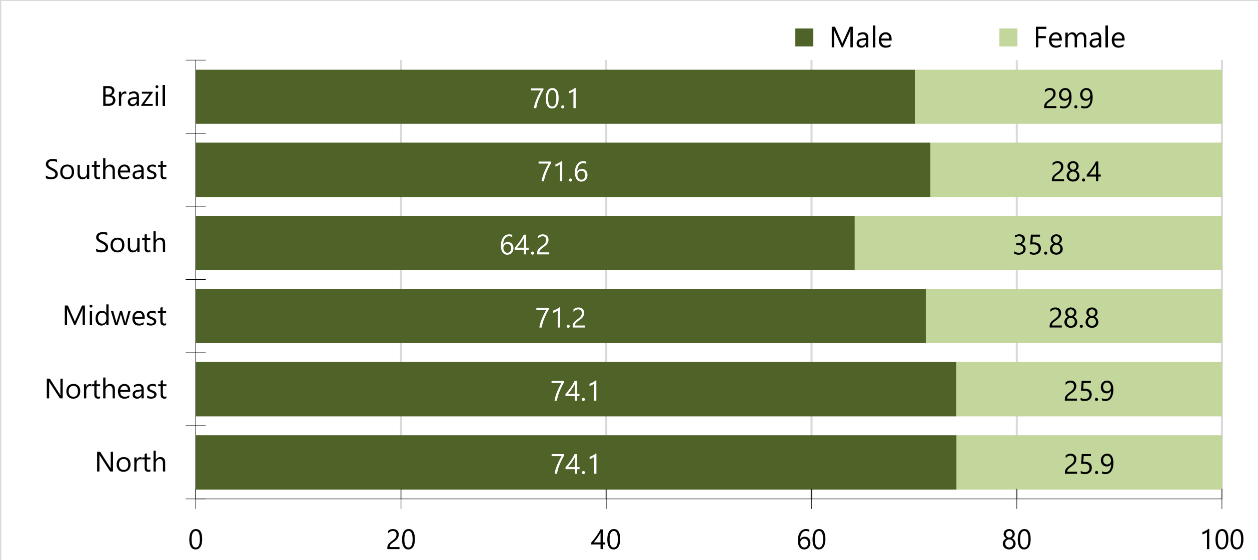


Source: Data from Labour Secretary of Brazil.

In 2011, the lagging North and Northeast regions employed a lower percentage of women than other regions (Figure 10). In practically all regions, men workers occupy positions at greater digitalisation risk than women workers, except in the Northeast (Figure 11).

[11] The North is an exception due to the presence of Zona Franca de Manaus, established through a regional development program that aimed to consolidate productive activities in a remote area of the country, granting tax benefits to local producers; this argument is detailed below.

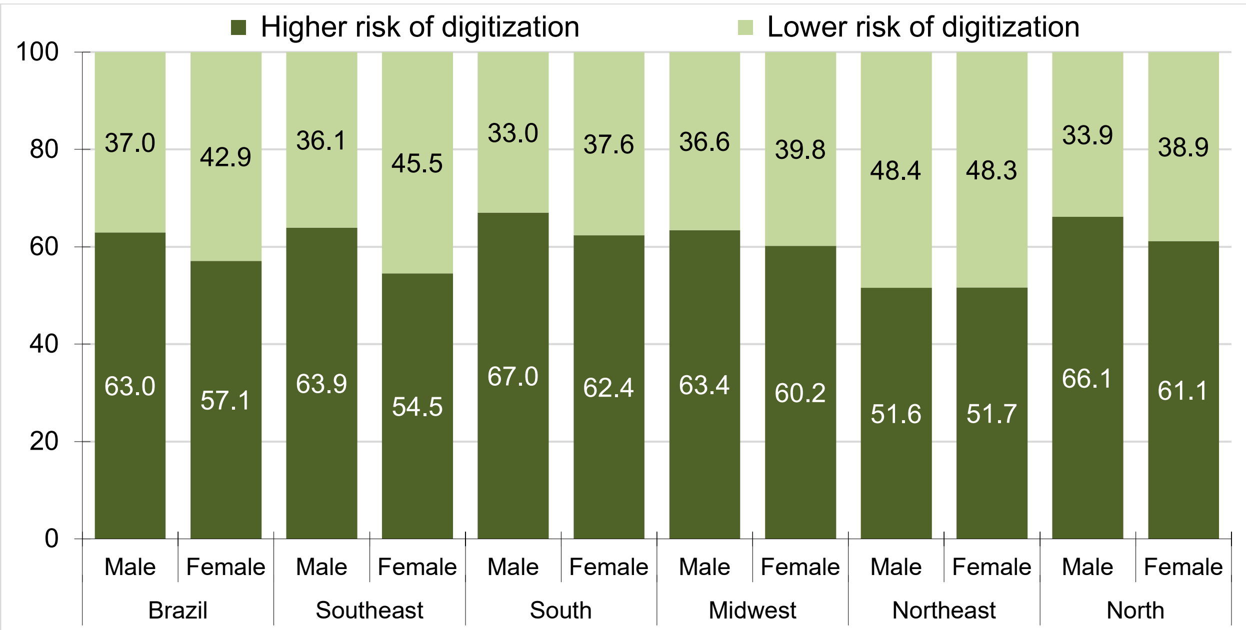
Figure 10: Distribution of manufacturing employment by gender and region (2011)



Source: Data from Labour Secretary of Brazil.

In Brazil, 63% of jobs filled by men were at high digitalisation risk against 57.1% of jobs filled by women in 2011 (Figure 11). The South had the largest share of men's jobs with a high digitalisation risk (67% of total occupations), followed by the North (66%). In the Southeast region, 54% of women employees were at greater risk of digitalisation, ten percentage points less than the male share in the same region; in the other regions, the difference between genders does not exceed five percentage points.

Figure 11: Share of male and female manufacturing employment by digitalisation risk by region (2011)



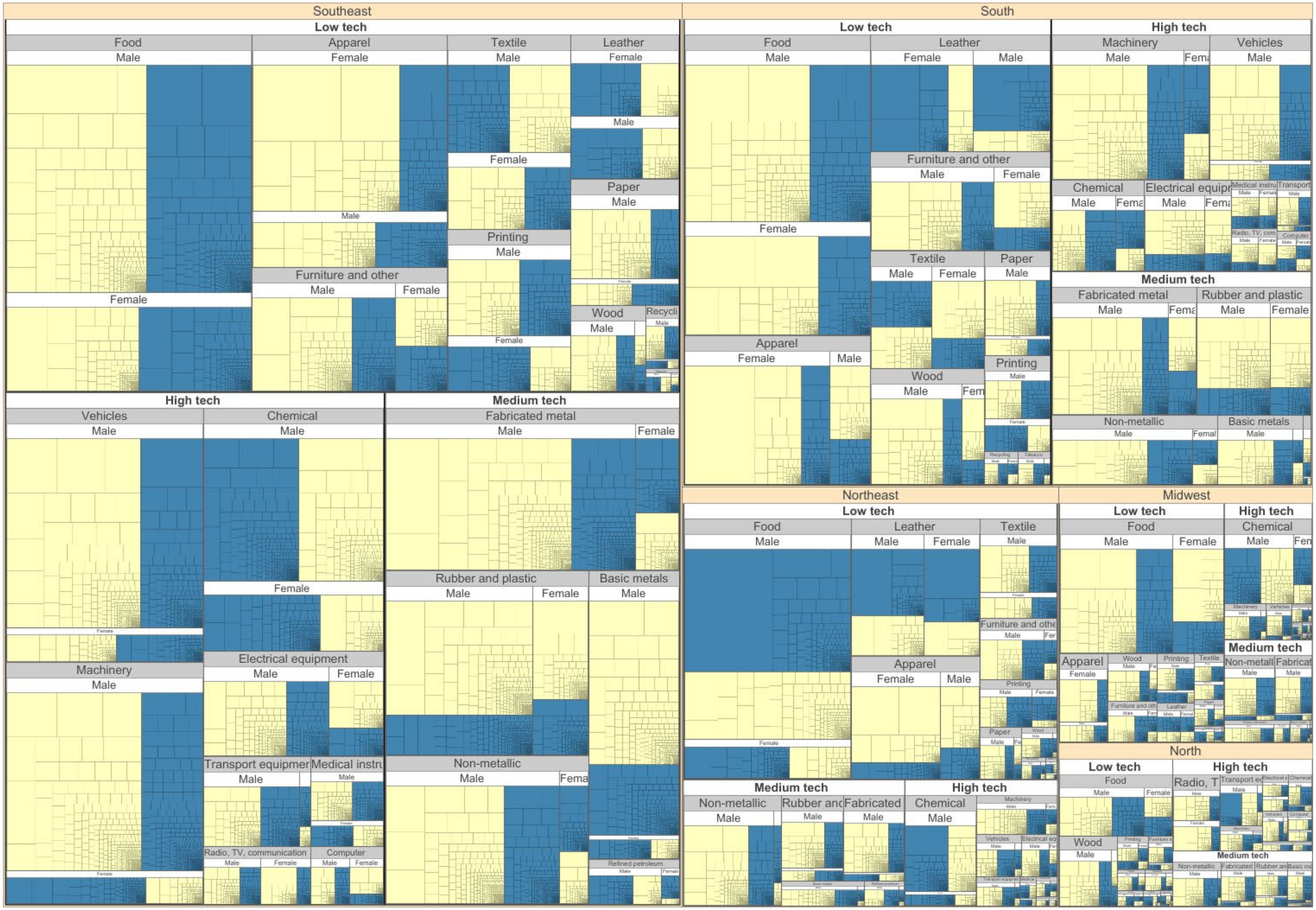
Source: Data from Labour Secretary of Brazil.

The evidence confirms our hypothesis that digitalisation risk varies by gender (and across Brazilian regions), being stronger for men. Now, we want to know if the regional distribution of manufacturing sub-sectors explains some differences.

Figure 12 shows the share of jobs at higher digitalisation risk in yellow and lower risk in blue, for all manufacturing sub-sectors by gender and regions in 2011. Figure 12 illustrates that the proportion of occupations with greater or lesser digitalisation risk can vary within the same sub-sector depending on geographic location. It is as if there were several countries with different production techniques located within one country. The food sub-sector illustrates this well.

For the food sub-sector, both the male and female share had a similar degree of digitalisation risk (50-50) in the Southeast. In the South and Midwest, both male and female jobs were at greater digitalisation risk, while in the Northeast, the opposite occurs.

Figure 12: Occupations by digitalisation risk in 2011 – by region, technology group, manufacturing sub-sector and gender



Source: Data from Labour Secretary of Brazil. Note: yellow represents higher risk occupations; blue represents occupations at lower risk of digitalisation.

Having depicted the job distribution profile in Brazil and its regions by the degree of digitalisation risk in the early 2010s, the next section assesses the changes – gain or loss of jobs – between 2011 and 2019. Are the jobs that declined the most in this period in Brazil those predicted by Frey and Osborne's (2017) study as being at high risk for digitisation?

Changes in employment in the past decade

Most of the information presented above is from 2011, giving a picture of the Brazilian manufacturing labour market in the initial year of this study from various perspectives. This section presents data on variation in employment – entrants minus departures – between 2011 and 2019. Our interest is to verify if the variation in jobs in that period was concentrated in the occupations most susceptible to digitalisation. We prepared an analysis of descriptive statistics, so we did not control for other factors – such as the impeachment of President Dilma in 2016 – that may have affected the variation in employment.[12]

Between 2011 and 2019, manufacturing employment shrank by 11.9% (Table 3). There was a loss of 936 017 jobs, concentrated in occupations identified as having a high digitalisation risk (Table 3). As mentioned earlier, 61.2% of manufacturing jobs had a high probability – equal to or greater than 75% – of digitalisation in 2011. Between 2011 and 2019, 67.5% of the jobs eliminated were concentrated in this type of occupation (Figure 13).

Women's and men's jobs declined by 300 000 and 635 000 respectively. The decline is also concentrated in jobs classified as high risk for both genders, with greater intensity for women (Table 3 and Figure 13). Losses in jobs with high digitalisation risk occupied by women exceeded occupations with lower risk by 3.7 times. This rate is more than halved for men (1.6 times).

Table 3: Manufacturing job change by digitalisation risk and gender, 2011-2019 (number of jobs)

Digitalisation risk	Male	Female	Total (2011-19)
Higher	-395 333	-236 931	-632 264
Lower	-239 839	-63 914	-303 753
All jobs	-635 172	-300 845	-936 017

Source: Data from Labour Secretary of Brazil.

We found a pattern by gender and region in the job variation over this period. For Brazil and all its regions, occupations with high digitalisation risk filled by women receded more than occupations filled by men; the opposite

[12] An analysis in this dimension requires an econometric approach.

happened in occupations with less risk of digitalisation (Table 4). In Brazil as a whole, the number of women's jobs shrank 17.6% against an 11.4% loss for men in high-risk occupations; in lower risk occupations, the variation was -11.7% for men and -6.3% for women. The other regions followed the same pattern, although employment has varied with different intensities.

Only the agricultural region (Midwest) showed positive growth in total employment, but occupations with a high digitalisation risk filled by women maintained a decrease of -6.9%.

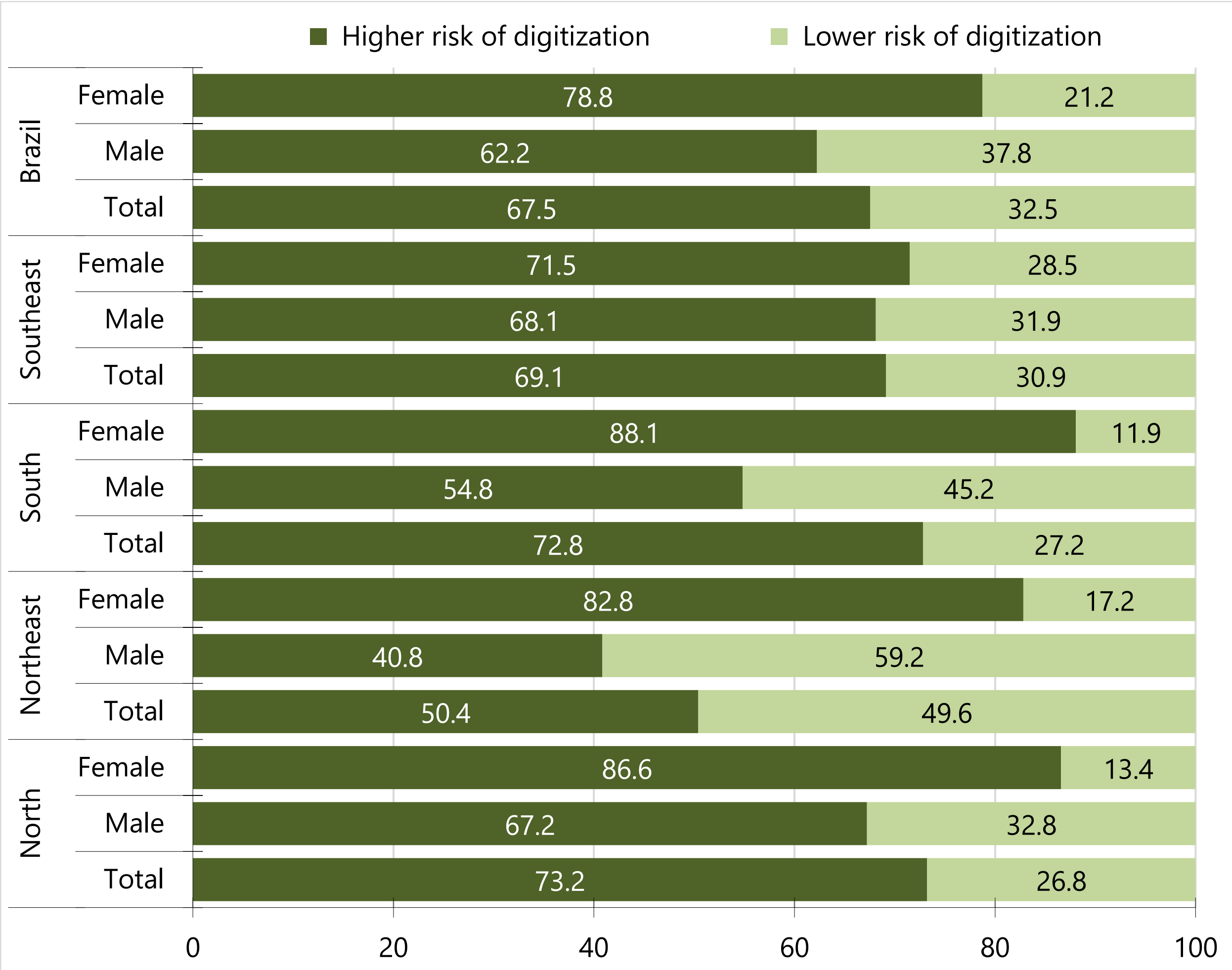
Table 4: Manufacturing job change between 2011 and 2019 by digitalisation risk, region, and gender (in percentages)

Regions	Digitalisation Risk	Occupations		
		Female	Male	Total
Brazil	Higher	-17.6	-11.4	-13.1
	Lower	-6.3	-11.7	-10.0
Southeast	Higher	-22.4	-17.0	-18.4
	Lower	-10.7	-14.1	-13.0
South	Higher	-11.2	-3.1	-5.9
	Lower	-2.5	-5.1	-4.1
Midwest	Higher	-6.9	7.4	3.4
	Lower	14.1	4.8	7.7
Northeast	Higher	-18.9	-11.0	-13.1
	Lower	-4.2	-17.0	-13.7
North	Higher	-28.7	-16.1	-19.2
	Lower	-7.0	-15.3	-12.9

Source: Data from Labour Secretary of Brazil.

Proportionally, female occupations classified as being at higher risk of digitalisation were the most vulnerable in the period (Figure 13). We showed that six out of ten women's jobs in 2011 were at high risk of digitalisation in Brazil. The difference between 2011 and 2019 was even worse, as eight out of ten women's jobs eliminated corresponded to high-risk occupations – reaching nine out of ten in the South region (Figure 13). For men, six out of ten jobs eliminated in manufacturing between 2011 and 2019 were in occupations at high risk of digitalisation, similar to the 2011 estimate.

Figure 13: Loss of manufacturing employment between 2011-2019 by digitalisation risk, region, and gender

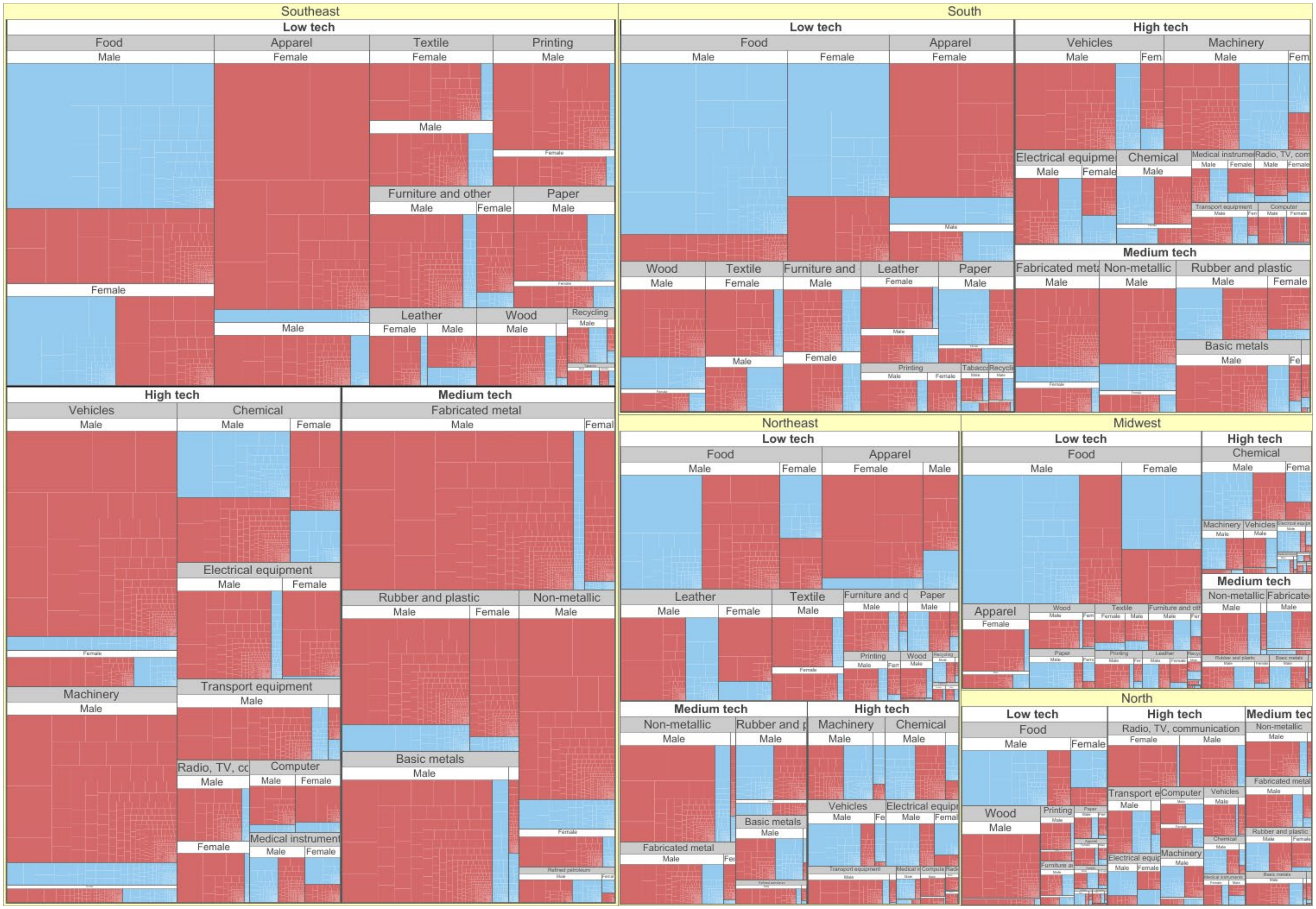


Source: Data from Labour Secretary of Brazil.

However, not all occupations classified as being at high risk of digitalisation declined between 2011 and 2019, although most of the jobs eliminated centre on them. We saw in the methodological section that there is an extensive list of 806 Brazilian occupations classified as being at high risk of digitalisation, following the article by Frey and Osborne (2017). Due to sectoral specificities, regional heterogeneities, different production techniques at the sub-sector-regional level and local dynamism, some occupations at high risk of digitalisation may have grown in the last decade.

We sought to calculate employment balance (positive or negative variation) in occupations at high risk of digitalisation by regions, sub-sectors, and genders. Figure 14 helps in this task. We calculated the change in the number of high-risk occupations between 2011 and 2019. Red indicates the occupations that have declined (negative variation) and blue the occupations with positive variation.

Figure 14: Change in occupations with higher digitalisation risk by region, technology group, manufacturing sub-sector, and gender (2011-2019)



Source: Data from Labour Secretary of Brazil. Note: red represents decline of occupations and blue represents increase of occupations.

The red stands out in Figure 14, which means the variation in the number of jobs in occupations at high risk of digitalisation was negative in most industries, in all regions and for both genders, which, in a way, gives strength to our study, as we are capturing occupations at greater risk of disappearing. However, there are some exceptions; the most prominent is the food sub-sector. Blue is predominant in the food sub-sector in all regions, both for men and women. It is one of the few manufacturing sub-sectors where high-risk occupations were created rather than eliminated in all regions.

Another exception is the chemicals sub-sector, where more high-risk jobs were created than eliminated in the Southeast region (in this case, only among men's jobs), South, Northeast and Midwest. Other sub-sectors have a low level of employment in the regions but are still generating jobs in occupations at high risk of digitalisation faster than they are being lost, as is the case for medical instruments in the Southeast region, plastic products in the South region (only for men), paper (only for men) in the South region, Northeast and Midwest, and electrical equipment in the North region (for men).

In summary, some points call our attention in Figure 14. First, the vast majority of occupations classified as being at a high digitalisation risk declined between 2011 and 2019. Second, the regional heterogeneity in the intensity of the decline in high-risk jobs between 2011 and 2019 is more remarkable than that predicted in 2011. Third, the largest decline in jobs in occupations at high risk of digitalisation between 2011 and 2019 occurred in women's jobs, contrary to the initial expectations. Fourth, the reduction in jobs at high-risk of digitalisation is quite uneven within regions by gender. Fifth, female jobs appear to be more vulnerable relative to male jobs in occupations most risk and less vulnerable in occupations at lower risk of digitalisation.

Discussion

Similarly to other studies regarding work digitalisation risk, our study found a similar percentage for Brazil, that 60% of manufacturing jobs are in occupations with a high risk of digitalisation. However, most of these jobs vulnerable to digitalisation concentrate in a few occupations that generate many jobs.

Motivated by deep regional inequalities, sub-sectoral capital and technology intensity characteristics, and gender division in the labour market, we combined data from the excellent Brazilian employment database to qualify the digitalisation risk by gender, sub-sector and region from a global South perspective.

Our study confirmed our hypothesis that men's jobs are more likely to be digitised than women's jobs. Men are concentrated in occupations more susceptible to digitalisation, in Brazil and all five macro-regions. However, the employment decline in such occupations over the past decade showed that women lost more jobs by percentage than men in all regions, reducing the already-low female share of manufacturing employment. This further aggravates the situation of women in the labour market, who already receive less than men for the same occupation and need to manage extra work hours in unpaid work (in Brazil, many women are family heads and single mothers). Additionally, it needs to be considered that, to successfully relocate in the job market, women will need different skills and more education, plus access to technological capabilities that match the requirements for working with modern technologies. That is why we argue that women are in a more vulnerable position in the labour market than men if the replacement by new technologies advances rapidly.

Part of the change in women's employment between 2011 and 2019 is due to the female share (in sub-sector employment) being higher precisely in sub-sectors where female jobs are at greater risk of digitalisation – apparel, textiles, radio, TV and communication, computers, rubber and plastic; the only exception is leather, which has a lower risk of digitalisation. These sub-sectors are labour-intensive and have suffered from intense Asian competition, especially from China (Morceiro, 2018; Morceiro & Guilhoto, 2020), contributing to the decline in employment.

Still, regarding gender inequality, it is noteworthy that women have a minimal share of jobs – less than 20% – in various high- and medium-tech industries with lower digitalisation risk. This is the case for machinery, transport equipment, basic metals, non-metallic, fabricated metal, refined petroleum, and, to a moderate degree, vehicles and chemicals.

Our hypothesis that more backward regions are at a lower risk of digitalisation than advanced ones was partially confirmed. The backward North region has a high share of employment in occupations with a high digitalisation risk, partially contradicting our hypothesis, which remained valid for the backward Northeast region. However, the North region has an industrial structure largely biased by industrial policies which grant tax subsidies to establish an industry in the heart of the Amazon rainforest. A local production incentive zone, the Zona Franca de Manaus, was planned for the North region and is home to several companies – many of them multinational – from the computer, radio, TV and communication, electrical equipment and food sub-sectors. There is a commitment to carry out minimal assembly activities – similar to Mexican *maquilas* – in exchange for tax subsidies (Morceiro & Guilhoto, 2020). In addition to the labour-intensive assembly activities in these sub-sectors, jobs are concentrated in occupations with a high digitalisation risk. So, it is understandable that the North resembles the most advanced regions in terms of the digitalisation risk.

More detailed data combinations by region, sub-sector, technology group and gender show that occupations with greater or lesser digitalisation risk vary for the same sub-sector or gender depending on geographic location. It is as if several countries with (slightly) different production techniques, geographically located within only one country; such are the heterogeneities and inequalities that exist in Brazil, as possibly in other global South countries.

Finally, the decline in jobs in high-risk occupations between 2011 and 2019 was even higher than the percentage of occupations at risk of being digitised in 2011 (61.2% were at high risk of digitisation in 2011 and, of the occupations lost between 2011 and 2019, 67.5% correspond to high risk occupations). We cannot say that the decline is due exclusively to digitalisation, as our nonparametric analytical exercise does not allow us to reach such a conclusion. In addition to this, other institutional problems hit the Brazilian economy in the past decade (a political crisis that turned into an economic crisis). There was also little structural change and modernisation in Brazilian manufacturing, especially in the second half of the period. That is why it is too risky to attribute the reduction of employment totally or majorly to digitalisation.

Concluding remarks

This study sought to connect the worlds of workers, new technologies, gender, industries and regional inequalities from a global South perspective. Based on the provocative article by Frey and Osborne (2017), several researchers have focused on understanding how the adoption of modern production technologies could replace human jobs through different approaches at the country level. We added detail to this question. We focused on Brazil, a global South country with characteristics different from the global North in economic, social and technical terms that limit the potential adoption of new technologies. We also focused on verifying inequalities across industries, gender and regions in terms of jobs that are most at digitalisation risk. We hypothesised that the risk to digitalisation might vary according to the distribution of manufacturing sub-sectors, the proportion of female and male employees, and the characteristics of each region of Brazil.

We created a correspondence table of occupations identified by Frey and Orsborne (2017) and a list of Brazilian occupations to verify these hypotheses. We calculated the number of jobs in 23 manufacturing sub-sectors, three technology groups, five regions and two genders, for 2011 and 2019. With this data, we sought to identify whether there were inequalities in the risk of digitalisation in three dimensions associated with the workforce profile (by gender), with manufacturing sub-sectors, and finally, with the regional distribution of industry and workers. In addition, we also sought to understand whether the recent drop in employment in Brazil was concentrated in occupations more or less sensitive to digitalisation.

Most jobs in the Brazilian manufacturing sector are at high risk of digitalisation. We verified substantial heterogeneity amongst manufacturing sub-sectors and intra-technological groups regarding the digitalisation risk.

The gender divide is also critical in the Brazilian labour market, reflected in high inequality in women's participation. The proportion of women workers reach its highest levels in a few labour-intensive low-tech subsectors and some high-tech subsectors in which assembly activities predominate. Such sub-sectors are precisely the same ones where women are most at digitalisation risk. Also, the largest decline in jobs in occupations at high risk between 2011 and 2019 occurred in the female portion of the labour market, contrary to the initial expectations.

We also confirmed inequalities at the regional level. Employment digitalisation risk is greater in regions with higher GDP per capita compared to the backward Northeast region. The backward North region has a similar risk as the richer regions, but it is guided by strong subsidy policies that have biased the industrial composition towards high-tech assembly sub-sectors.

Although all Brazilian regions except the Midwest registered a drop in employment from 2011 to 2019, there is regional inequality in the intensity of the job loss. The drop was most significant in occupations with the highest digitalisation risk and even more pronounced among women in all regions. However, not all occupations classified as being at high risk of digitalisation experienced a decline in employment; especially in the food and chemicals sub-sectors, there was a positive balance. Future studies could investigate whether this decline in employment is due to technological modernisation or other factors related to industrial competitiveness.

We conclude that the share of jobs in occupations most at risk from digitalisation is very heterogeneous regionally, sub-sectorally, by gender and for all combinations of region, gender and sub-sector. This heterogeneity is probably also repeated in other global South countries. Therefore, such inequalities are crucial elements for designing educational, regional, social, labour, and science and technology public policies.

First, special attention should be given to female share, with policies that bring more women into the formal labour market. Policies that offer better conditions for conciliating work and family life are particularly effective.

Second, considering that cognitive and digital skills will provide additional protection against the risk of replacement due to new technologies, primary education and professional training policies must focus on these types of skills. Retraining workers, especially women who are in positions more sensitive to digitalisation, is critical for them to remain in work and move into higher-paying occupations with less risk of replacement. This could be done through direct contact between companies and professional training schools to, first, list the types of skills that companies are demanding, and second, formulate practical training for occupational requalification aimed at these skills. A common complaint among company leaders is that professional training focused on theoretical learning or outdated production techniques does not help the professional relocation of workers.

Third, while many occupations face a high risk of digitalisation, significant employment is concentrated in a few of them. Upskilling programs could focus on such occupations with policies that consider their skills to develop new tasks required by new technologies.

Fourth, to encourage a new generation of workers equipped for technological transformations, a greater spread of STEM professions, especially among women, could help reduce the proportion of occupations at high risk of digitalisation in the future. In Brazil, the fraction of newly graduated professionals in STEM is still relatively small. To increase interest in STEM professions, it is critical improve the quality of primary education (especially in mathematics) so that such courses are not seen as an insurmountable challenge, as well as to design social programs so that heads of households and girls can balance unpaid housework with the study time needed for professional training in STEM fields.

Fifth, informality and surplus labour in Brazil are high in all regions, especially in the most backward, although it affects the manufacturing sector to a lesser extent than other sectors. In this sense, local development programs to increase industrial diversity in backward regions are essential to improve local working conditions, making regional jobs more resilient to technological changes.

Finally, although six out of ten jobs in the formal labour market are at high risk of digitalisation in the future, it does not mean that all of them will be eliminated, nor does it tell us at what speed they may be eliminated. It is worth remembering that technological change in the global South is very slow compared to the global North. As labour is relatively cheap in global South countries due to informality, disguised employment and unemployment, it inhibits the replacement of workers by machines. In addition, the Brazilian industrial structure comprises companies at various technological stages, with Second and Third Industrial Revolution technologies coexisting, and little readiness for Fourth Industrial Revolution technologies. Finally, several regions lack basic transport, electricity and communication infrastructure, the latter being vital for the digitalisation process. Therefore, certain backward conditions shield some regions from technological transformation, but from another point of view, these give scope for public policies to attenuate negative impacts.

References

Acemoglu D. and Autor D.H. 2010. Skills, tasks and technologies: implications for employment and earnings. *NBER Working Paper Series 16082*. Cambridge.

Acemoglu D. and Restrepo P. 2018a. Artificial intelligence, automation and work. *NBER Working Paper Series n.24196*. Cambridge.

Acemoglu D. and Restrepo P. 2018b. Low-skill and high-skill automation. *Journal of Human Capital* 12(2).

Adamczyk W.B., Monasterio L. and Fochezatto A. 2021. Automação e ocupações no Brasil: novas estimativas. *Anais do 49º Encontro Nacional de Economia*. ANPEC.

Albuquerque P.H.M., Saavedra C.A.P.B., de Morais R.L. and Peng Y. 2019. The robot from Ipanema goes working: Estimating the probability of jobs automation in Brazil. *Latin American Business Review* 20(3).

Andreoni, A. 2019. Robotising Regions: A Comparative Analysis of Industrial Policy for Robotisation across China , Malaysia and Thailand (Report). (Community of Practice in Innovation and Inclusive Industrialisation. DST/NRF South African Research Chair). Pretoria.

Arntz M., Gregory T. and Zierahn U. 2016. *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis.* (189). Paris: OECD Publishing.

Autor D.H. and Dorn D. 2013. The growth of low-skill service jobs and the polarization of the US Labor Market. *American Economic Review* 103(5).

Autor D.H., Levy F. and Murnane R.J. 2003. The skill content of recent technological change: an empirical Exploration. *The Quarterly Journal of Economics* 118(4).

Azzoni C.R. and Haddad E.A. 2018. Regional disparities. In Amann E., Azzoni C.R., and Baer W. (Eds.) *The Oxford Handbook of the Brazilian Economy*. Oxford: Oxford University Press.

Berger T. and Frey C. 2016. *Structural Transformation in the OECD: Digitalisation, Deindustrialisation and the Future of Work*. Paris: OECD Publishing.

Brussevich M., Dabla-Norris E., Kamunge C., Karnane P., Khalid S. and Kochhar K. 2018. Gender, Technology, and the Future of Work. IMF Staff Discussion Note 18/07. Washington, DC: IMF.

Brynjolfsson, E. and McAfee, A. 2014. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. Washington, DC: WW Norton & Co.

Bucciferro J.R. and Ferreira de Souza P.H.G. 2020. The Evolution of regional income inequality in Brazil, 1872–2015. In Tirado-Fabregat H., Badia-Miró, Willebald M., (Eds.). *Time and Space. Palgrave Studies in Economic History*. Camden: Palgrave Macmillan.

Chang J.H. and Huynh P. 2016. ASEAN in transformation: the future of jobs at risk of automation. *International Labour Office Bureau for Employers' Activities, Working Paper 9*.

Charles K.K., Hurst E. and Notowidigdo M.J. 2013. Manufacturing decline, housing booms, and non-employment. *NBER Working Paper 18949*. Chicago.

Davies R. and van Seventer D. 2020. Labour market polarization in South Africa: A decomposition analysis. *UNU-WIDER Working Paper 2020/17*.

Eden M. and Gaggl P. 2015. Do poor countries really need more IT ? The role of relative prices and industrial composition. *World Bank Group Policy Research Working Paper 7352*.

Ehrl P. and Monasterio L. 2019. Skill concentration and persistence in Brazil. *Regional Studies* 53(11).

Ferraz J.C., Kupfer D., Torracca J. and Britto J.N.P. 2020. Snapshots of a state of flux: how Brazilian industrial firms differ in the adoption of digital technologies and policy implications. *Journal of Economic Policy Reform* 23(4).

Frey C.B. and Osborne M.A. 2017. The future of employment: how susceptible are jobs to computerisation? *Technological Forecasting and Social Change* 114(1).

Galetti J.R.B., Tessarin M.S. and Morceiro P.C. 2021. Skill relatedness, structural change and heterogeneous regions: evidence from a developing country. *Papers in Regional Science* 100(6).

Graetz G. and Michaels G. 2018. Robots at work. *The Review of Economics and Statistics*. 100(5).

Haussmann S. and Golgher A.B. 2016. Shrinking gender wage gaps in the Brazilian labor market: an application of the APC approach. *Nova Economia* 26(2).

Kang T.H., Paese L.H.Z. and Felix N.F.A. 2021. Late and unequal: measuring enrolments and retention in Brazilian education, 1933-2010. *Revista de Historia Económica/Journal of Iberian and Latin American Economic History* 39(2).

Lorenz E., Tessarin M.S. and Morceiro P.C. 2019. 4th Industrial Revolution 'deep dive' policy brief 2: evidence from sector case studies. Community of Practice in Innovation and Inclusive Industrialisation. Pretoria: DST/NRF South African Research Chair.

Madgavkar A., Manyika J., Krishnan M., Ellingrud K. and Yee L. 2019. *The future of women at work*. New York: McKinsey Global Institute.

Mariscal J., Mayne G., Aneja U. and Sorgner A. 2019. Bridging the gender digital gap. *Economics* 13.

Morceiro P.C. 2018. Evolution and sectoral competiveness of the Brazilian manufacturing industry. In Amann E., Azzoni C.R., and Baer W. (Eds.). *The Oxford Handbook of the Brazilian Economy*. New York: Oxford University Press.

Morceiro P.C. and Guilhoto J.J.M. 2020. Productive densification and hollowing-out process in Brazilian manufacturing. *Economia e Sociedade* 29(3).

Nassif A. and Morceiro P.C. 2021. Industrial policy for prematurely deindustrialized economies after the Covid-19 pandemic crisis: Integrating economic, social and environmental goals with policy proposals for Brazil. *Faculdade de Economia-UFF Working paper 351*.

OECD. 2015. *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence*. Paris: OECD Publishing.

OECD. 2017. *Getting Skills Right: Skills for Jobs Indicators*. Paris: OECD Publishing.

OECD. 2018. *Bridging the digital gender divide: Include, Upskill, Innovate*. Paris: OECD Publishing.

Reis E. 2014. Spatial income inequality in Brazil, 1872–2000. *EconomiA* 15(2).

Sorgner A. 2019. The impact of new digital technologies on gender equality in developing countries. *UNIDO Inclusive and Sustainable Industrial Development Working Paper Series 20*.

Sorgner A., Bode E., Christiane K.B., Aneja U., Coleman S., Mishra V. and Robb A.M. 2017. *The effects of digitalization on gender equality in the G20 Economies*. Kiel: Kiel Institute for the World Economy.

Tessarin M.S., Morceiro P.C., Chagas A.L.S. and Guilhoto J.J.M. 2020a. Sectoral proximity in the Brazilian manufacturing industry. *Nova Economia* 30(3).

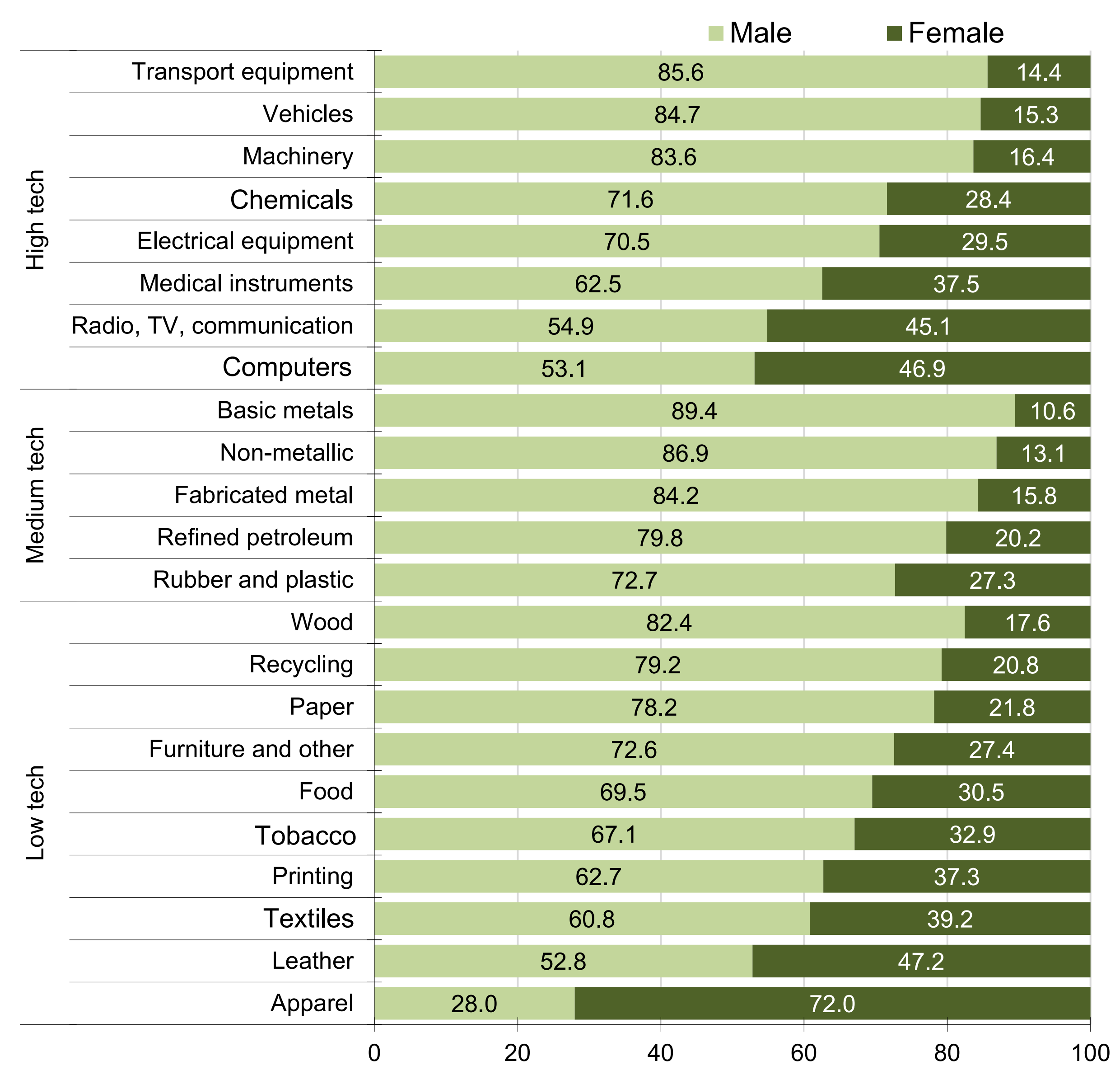
Tessarin M.S., Suzigan W. and Guilhoto J.J.M. 2020b. Cooperation to innovate in Brazil: differences according to firms' technological intensity and origin of capital. *Estudos Econômicos* 50(4).

UNIDO. 2017. *International Yearbook of Industrial Statistics 2017*. Cheltenham: Edward Elgar Publishing.

UNIDO. 2010. *Industrial Statistics: Guidelines and Methodology*. Vienna: UNIDO.

Appendix A

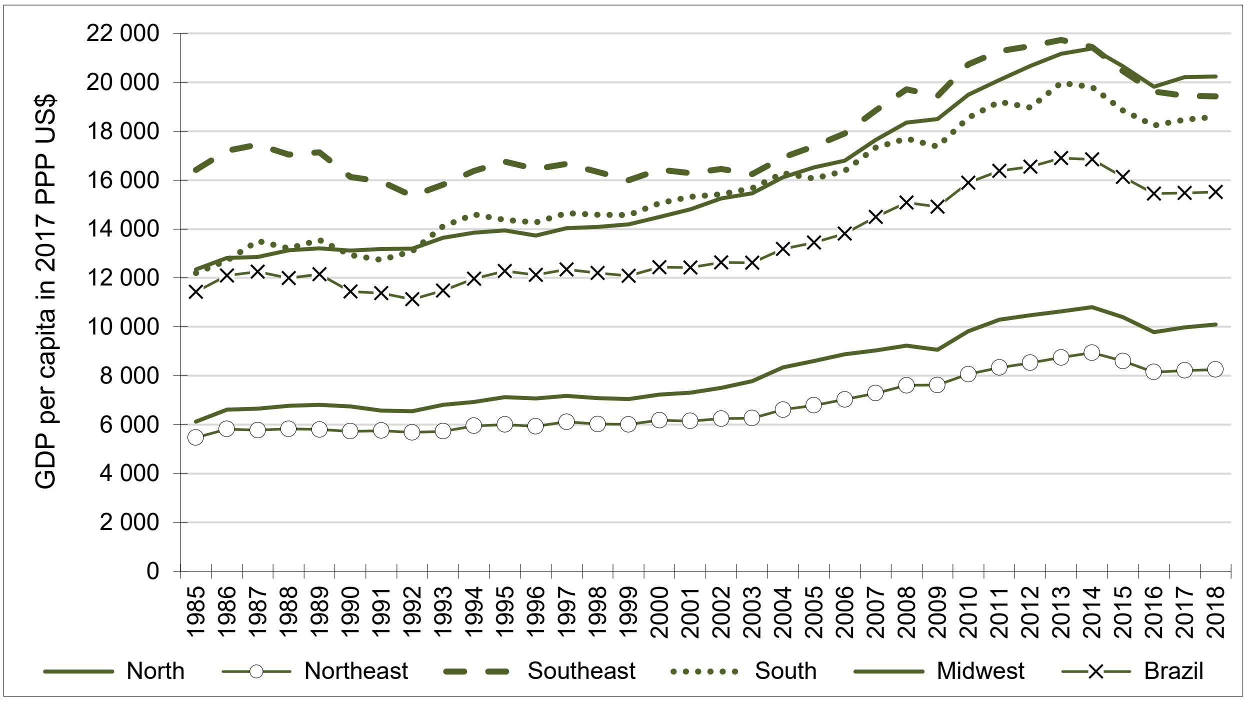
Figure A.1: Distribution of employment in Brazil's manufacturing sub-sectors by gender (2019)



Source: Data from Labour Secretary of Brazil.

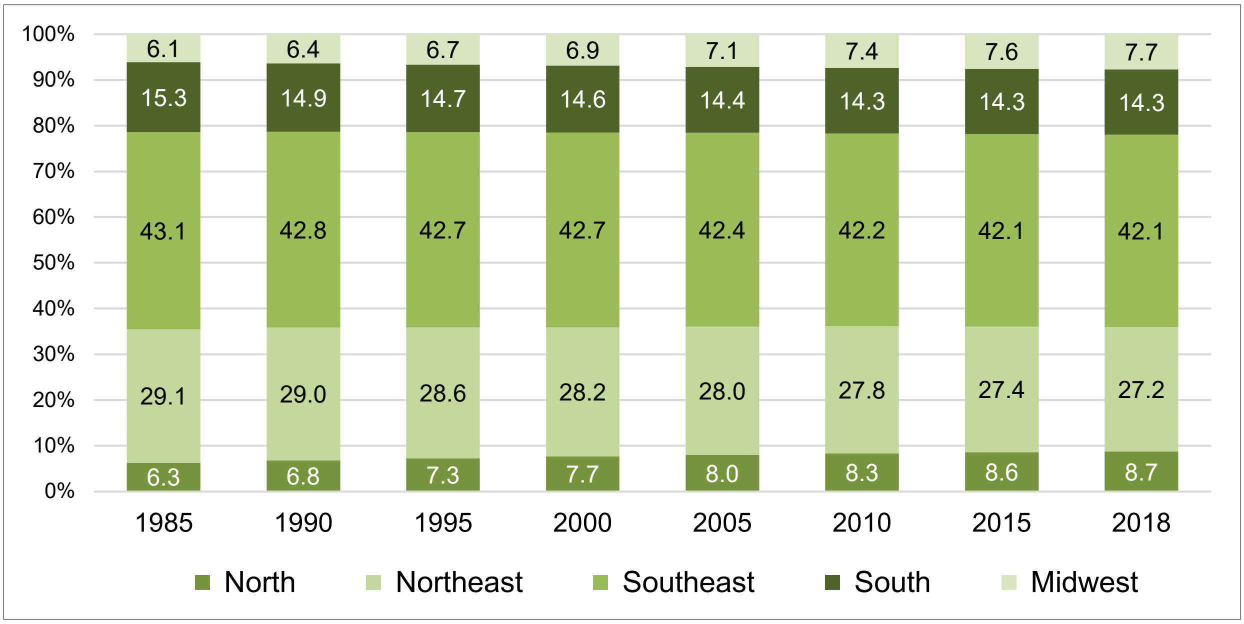
Appendix B

Figure B.1: GDP per capita by regions of Brazil, 1985-2018



Source: Brazilian Institute of Geography and Statistics (IBGE) and The Conference Board.

Figure B.2: Population distribution by regions of Brazil, 1985-2018



Source: Brazilian Institute of Geography and Statistics (IBGE).