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**THE HETEROGENEITY OF
ORGANIZATIONAL STRUCTURE
CHANGES IN BRAZILIAN FIRMS WITH
THE ARRIVAL OF THE INTERNET**

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THE HETEROGENEITY OF ORGANIZATIONAL STRUCTURE CHANGES IN BRAZILIAN FIRMS WITH THE ARRIVAL OF THE INTERNET

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ABSTRACT

After the privatization of telecommunications companies in Brazil in the late 1990s, Brazilian cities experienced an expansion of internet services. This paper analyzes the impact of this technological shock on the relative employment of managers between sectors according to their technological intensity. We combine three distinct sources of information to build a rich database in which the observation level is defined by combinations of detailed sectors, municipality and year. As internet rollout across municipalities was not random, we rely on a triple difference approach for our empirical strategy. Our results show a more pronounced effect of internet arrival on the share of managers, in technology-intensive sectors. In other words, internet arrival contributed to a higher concentration of top jobs in high tech sectors. This result raises concerns that technologies may exacerbate inequalities in the labor market.

Keywords: Technology; communication; organization; labor; RAIS.

1 INTRODUCTION

The introduction of new technologies usually demands changes in a company's production structure and organization. These changes may lead to a new set of tasks for workers to perform and/or a new distribution of tasks among different groups of workers. For instance, there is a substantial body of literature documenting an increased demand for workers who perform non-routine tasks as a consequence of the introduction of automated equipment - e.g., Autor, Levy and Murnane (2003); Goos and Manning (2007); Spitz-Oener (2006).¹ This branch of the literature highlights that this reallocation in the demand for types of tasks performed by workers can occur differently even among firms within the same sector of activity.

However, it is expected that the degree of adjustment to technological shocks tends to differ across sectors, depending on the reliance on the technology being replaced or the potential benefits of the new technology. In this paper, we analyze whether task reallocation among workers is more intense in sectors that are more likely to be affected by new technology.

In order to analyze the relative impact across sectors, it is appropriate to focus on a technology with a broad range of potential applications. For this reason, we choose the advent of the internet as the subject of our study rather than automation as the technological change.

Brazilian municipalities experienced a rapid expansion of internet services in the late 1990s. In 1999, 15% of municipalities had some private internet service, while by 2009, this figure had grown to approximately 55% (IBGE, 1999; 2009). This digital progress reached Brazilian firms as well, with about 76.9% of companies with one or more employees using the internet by 2010 (IBGE, 2010). This paper aims to explore the growth of internet provision in Brazilian municipalities as a technological shock capable of heterogeneously impacting the organizational structure of Brazilian firms across different sectors of activity. To capture the organizational structure, we chose to analyze the intensity of employment in managerial positions. This methodological choice is supported by a framework in which tasks can be divided into: i) directly related to production; and ii) problem-solving. Garicano (2000) proposes a theoretical model within this framework where firms organize hierarchically to optimize the allocation of knowledge for the efficient resolution of operational problems. According to the author,

1. This literature is often referred to as "Task Approach".

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this optimization affects the hierarchical structure of firms, especially the share of workers in managerial positions, where tasks are focused on problem solving.

The advent or development of information and communication technologies (ICT), such as the internet, can prompt revisions to this optimization. Bloom et al. (2014) use Garicano (2000) framework to derive theoretical predictions regarding advances in ICT. The authors show that advancements in the communication aspect of ICT can make it more efficient to centralize problem-solving among higher-ranking workers (managers), thereby reducing the autonomy of other workers. Conversely, advancements in the information technology component of ICT enable lower-level workers to make decisions more autonomously, relying less on managers for problem-solving.²

That is, the communication and information dimensions of the internet (as an ICT) lead to different theoretical predictions. Thus, the purpose of this paper is to empirically analyze whether the introduction of the internet in Brazilian municipalities has operated as predicted by the communication dimension of this technology, increasing the relative employment of managers, or conversely, as predicted by the information dimension of this technology. Once again, we emphasize that the effect we seek to identify is relative to the propensity of the sector to use the internet.

We will rely on Brazilian data from *Relação Anual de Informações Sociais* (RAIS) an exceptional registry of formal workers with detailed information about their occupations. In particular, the information available in RAIS allows us to identify workers holding managerial positions in their firms. We complement our analysis with municipal data containing records of the presence of Internet services, as collected by the Instituto Brasileiro de Geografia e Estatística (IBGE). In 1999, one year after the privatization of the Telebrás communication company, *Pesquisa de Informações Básicas Municipais* (MUNIC) by IBGE investigated which municipalities had private internet service. Subsequently, this specific question appeared in the years 2001, 2005, and 2006, and therefore, the present study aims to examine this period.

Our database is organized in a panel format, where the observation unit in the cross-sectional dimension is an interaction between sector and municipality. Once again, we emphasize that the effect we want to identify is relative to the sector's propensity to use the internet. The empirical strategy we adopted was triple difference. That is, in addition to contrasting the changes in the ratio of managers between units according to

2. The analysis by Gurbaxani and Whang (1991) was already pointing in a similar direction.

the availability of internet provided by their respective locations (whether internet arrived or not), we also contrast the changes in the ratio of managers between sectors with higher or lower potential internet usage. To incorporate this third sectoral dimension, we relied on a variable created by Oldenski (2014) using data from the North American CPS. The 2003 supplement provided information on computer use at work, which was then aggregated by industry.

Our results indicate that the arrival of the internet led to a relatively higher increase in the ratio of managers in sectors that tend to use this technology more. Under Bloom et al. (2014) framework, this finding suggests that, at least for these sectors, the communication dimension of the internet was the one that most affected Brazilian firms when this technology began to spread in Brazil.

The adjustment of Brazilian companies to the introduction of the internet has a concerning aspect regarding inequality, as it indicates that technology-intensive sectors will allocate workers more intensively to positions that require higher qualifications and pay higher wages.

The identification hypothesis underlying our analysis is that any differences in the evolution of the ratio of managers between sectors are homogeneous across locations that did or did not receive the internet. In order to validate the model, a cross-sectional placebo test was carried out for the year 1999 in order to analyze the behavior of the variable of interest prior to the shock, identifying in the specification the municipalities that adopted the internet early and those that adopted it late.

In addition to the studies whose theoretical contributions we have already mentioned, our article relates to several empirical studies on technology and the labor market. Among these contributions, the most relevant for our study is the empirical exercise conducted by Bloom et al. (2014), which tests both the effects of communication technologies and information technology on worker autonomy. Through a survey of approximately 4,000 firms in the United States, Europe, and Asia, the authors conclude that it is easier for workers in high hierarchy positions to make decisions when communication costs are low, while worker autonomy is positively affected by the reduction in information costs.

In a complementary strand, there are authors who investigate how organizational changes affect the demand for skills in the labor market, highlighting the relationship between organization, task allocation for different competencies, and technology (Acemoglu et al., 2007; Bresnahan, 1999; Dessein and Santos, 2006).

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Following the introduction, Section 2 provides a theoretical synthesis, referring to communication as a disaggregated technological shock and how it relates to occupational structure. Section 3 describes the data and variables of interest. The empirical strategy is presented in section 4, the results in section 5 and the conclusion in section 6.

2 ANALYTICAL FRAMEWORK

Our empirical exercise can be theoretically grounded in the framework proposed by Garicano (2000). In this theoretical model, firms are organized hierarchically to achieve maximum efficiency in problem solving. Understanding the model involves some initial definitions of production and communication within the organization.

First, the author assumes that production requires physical effort and knowledge. A practical example is a machine operator who encounters a series of problems that need to be solved for the machine to work.

Garicano (2000) starts from the idea that different workers acquire different sets of knowledge and that knowledge is communicated within an organizational system. While this is advantageous as it reduces learning costs and solves activities more efficiently, it also incurs costs, as it is not trivial to assign a worker to a specific problem and the solution needs to be communicated. Communication is costly because when a low-level hierarchical worker cannot solve a problem, it is passed on to the next hierarchical layer.

The authors describe that each operational worker has a set of problems $[0,1]$ per unit of time, and the cost of acquiring knowledge is defined in the interval $[0,z]$, where z represents the problems preceding production. The cost is unique to the worker and depends on available technologies and their characteristics. Managers have the ability to reduce knowledge costs in allocating workers to solve problems or solve them themselves, so operators deal only with a portion of the problems in the interval $(0,)$, where 0 represents the problems they can solve. In this case, the cost incurred when activating a decision maker is called the help cost, h .

Some problems are more frequent than others, and for the authors, there is a density of problems that is graphically decreasing. This means that as operators learn the more frequent problems, they will communicate less frequently. The authors call this exception management, which means that operators deal with more routine problems and managers with exceptions.

Considering that a team deals with N problems per unit of time during production, the team needs N operational workers and managers. The authors define managerial span s as the ratio $N/$, which implies that the more knowledge the operators have, the fewer managers are needed. The firm's problem is to decide the size of the hierarchy s and the degree of worker autonomy .

Bloom et al. (2014) show that, given the settings of the model, it is possible to make theoretical predictions about the effects of changes in the cost (or availability) of both communication and information technologies. First, a decrease in communication costs reduces worker autonomy and has an ambiguous effect on managerial span s , i.e., more questions are asked but less time is spent. On the other hand, a decrease in the cost of information to the operational worker or manager improves worker decision making and increases managerial span because fewer questions are asked.

To test this proposition, they combine microdata from the Management and Organization Survey (CEP), developed by Bloom and Van Reenen (2007), with the Information and Communication Technology panel from Harte-Hanks in the United States, Europe, and Asia to measure worker autonomy, plant manager decision-making level, and compile software and hardware data.

The authors investigate these effects on three different dependent variables: plant manager autonomy, worker autonomy, and plant manager span of control. The latter is the one that interests us the most and is identified by how many people report to each manager in the organization.

Regarding the main explanatory variables, the use of Enterprise Resource Planning (ERP) was the primary variable to capture the intensity of information technology use, while the use of Computer Assisted Design (CAD) and Computer Assisted Manufacturing (CAM) and data intranet was used to capture the intensity of communication technology use. They found that communication technologies decrease autonomy for workers.

This study acknowledges the heterogeneous nature of technology discussed in the above theory and seeks to advance empirically with robust data from Brazilian workers by testing whether an information and communication shock in municipalities increases the ratio of managers in firms.

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3 DATA AND DESCRIPTIVE STATISTICS

The data sources used are RAIS from the Ministry of Labor, MUNIC from IBGE and Current Population Survey (CPS) from the United States Census Bureau. The database consists of observations of interaction between sector, municipality, and year. The sectors are characterized by the first four digits according to Classificação Nacional das Atividades Econômicas (CNAE 1.0),³ which in total have five digits. The municipalities are identified by the first 6 digits according to the IBGE municipality code, and the observed years are 1999, 2001, 2005, and 2006. The ratio of managerial positions, the main variable of interest, is aggregated by RAIS. The explanatory variables, municipal internet service, and industrial technological intensity, are obtained respectively from MUNIC and CPS.

The proportion of managerial positions, the main variable of interest, is computed using RAIS for each combination of sector, municipality, and year. The explanatory variables, municipal internet service and industrial technological intensity, are obtained from MUNIC and CPS, respectively.

The years 1999, 2001, 2005 and 2006 were chosen because these are the years in which MUNIC investigated whether a given municipality had a private internet service. In total, there are 353,889 observations, each representing the sector-municipality interaction in an unbalanced panel over four years.

It is worth noting that the number of municipalities has increased over the years, so the number of observations for each year will not be the same. According to MUNIC, 5,507 municipalities were surveyed in 1999, while in 2006 the number of observations was 5,564, resulting in a difference of 57 municipalities. In addition, as is common in the literature, a filter was applied to remove observations with less than five employees. Therefore, it is possible that from one year to another, sectors (at the 4-digit level) that did not have observations due to the size of the establishments included may have started to have them if the number of employees increased, and vice versa. These are the main factors that lead to the panel being unbalanced.

3. Due to coverage issues, we chose to exclude the following sectors: agriculture, livestock, forestry, and logging (section A of CNAE), fishing (section B), and public administration (section L). This study opts to use CNAE 1.0, as CNAE 2.0, currently in use, was released starting in 2007, while our analysis ends in 2006.

3.1 Relative Employment of Managers

This study focus on the relative employment of workers in managerial positions defined by three possibilities of occupational classes available in our data: executives, directors, and managers. These groups can be identified by Brazilian Classification of Occupations (CBO) codes, from the Ministry of Labor, available in RAIS. The identification allows to determine the total number of workers and those in these occupations aggregated by sector, municipality and year. The RAIS record is one of the most reliable for monitoring a worker over the years, and its completeness allows integration with other databases (Dix-Carneiro, 2014).

There are two classifications of CBO, one from 1994 and the one currently used, from 2002. This work follows the most current classification for the years 2005 and 2006 and a conversion provided by the Ministry of Labor for the years 1999 and 2001. The main differences are illustrated in table 1. The current structure comprises, in order, major groups, main subgroups, subgroups, families, and occupations. These are layers that help categorize occupations into codes to follow an international standard.

There are 10 major groups, from digit 0 to digit 9, and group 1 represents senior members of the public sector, leaders of public interest organizations and companies, and managers. At the two-digit level, where the initial digit is 1, there are four main subgroups: public sector members, executives, directors, and managers. It is not part of the goal of this paper to analyze worker allocation in the public sectors, so only the latter three were included.⁴ It is understood that this level is sufficient to identify the variables of interest in this study and that the conversion does not significantly affect comparison over the years. The descriptions of these occupations coincide with typical managerial roles and are identified through imperative verbs such as coordinate, supervise, manage, lead, execute, and others.

Descriptively contextualizing some aspects of the country's workforce during the studied period, it can be affirmed that the position of manager is more common than the others, with 335,519 observations in 1999 and 1,007,319 in 2006. The other managerial positions, directors and executives, occupy a higher class in the hierarchical structure and therefore have fewer observations, but still increase in quantity over the eight years studied. In 2006, there were 27,296 executives and 63,236 directors within the formal workforce registry (excluding sectors A, B, and L of CNAE 1.0 and applying the aforementioned filters).

4. For the subgroup of executives, there are 13 different occupations, while for directors, there are 40, and for managers, 63.

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TABLE 1
CBO structure 1994 and 2002

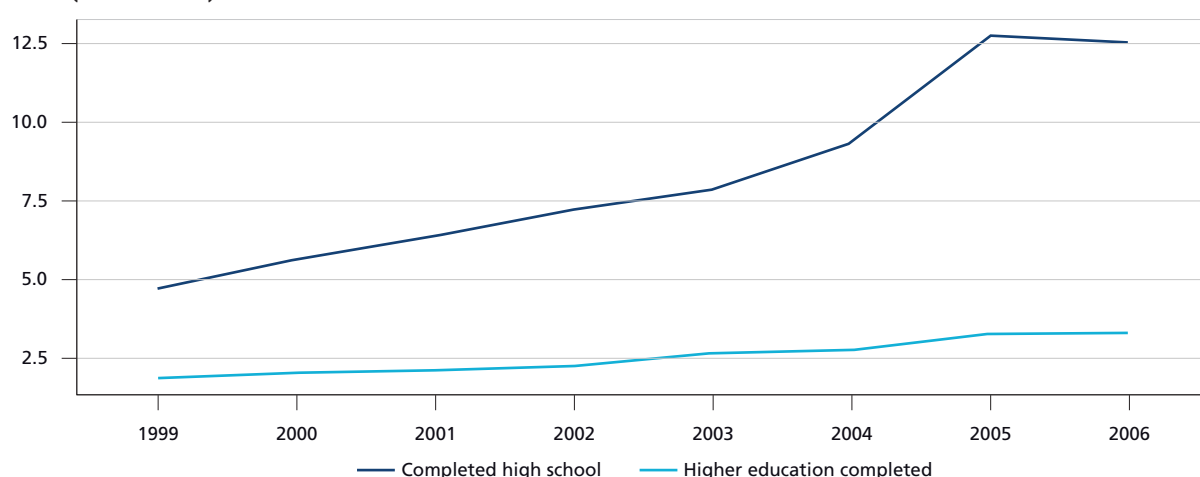
Structure	CBO 1994	CBO 2002	Digits
Big Groups	8	10	1
Main Subgroup	-	48	1 to 2
Subgroup	86	192	2 to 3
Base Groups or Family	353	607	3 to 4
Occupations	2356	2511	5 to 6

Source: MTE (1994; 2002).

Obs.: The table shows, in the first two columns, the differences between the structures of the 1994 CBO and the 2002 CBO. The third column refers to how many digits of the code refer to the structural level in 2002.

In addition to the quantity of managerial workers, during this period, the country also experienced a significant increase in the number of workers with completed high school and higher education, as illustrated by figure 1, indicating an improvement in the qualification of the Brazilian formal workforce.

FIGURE 1
Trends in the number of total workers with complete secondary education and complete higher education (1999-2006)
(In million)



Source: MTE, 1999; 2000; 2001; 2002; 2003; 2004; 2005; 2006.

Obs.: The observations come from the RAIS. Workers in sectors A, B and L, according to CNAE 1.0 and employed in establishments with fewer than 5 workers, were not taken into account.

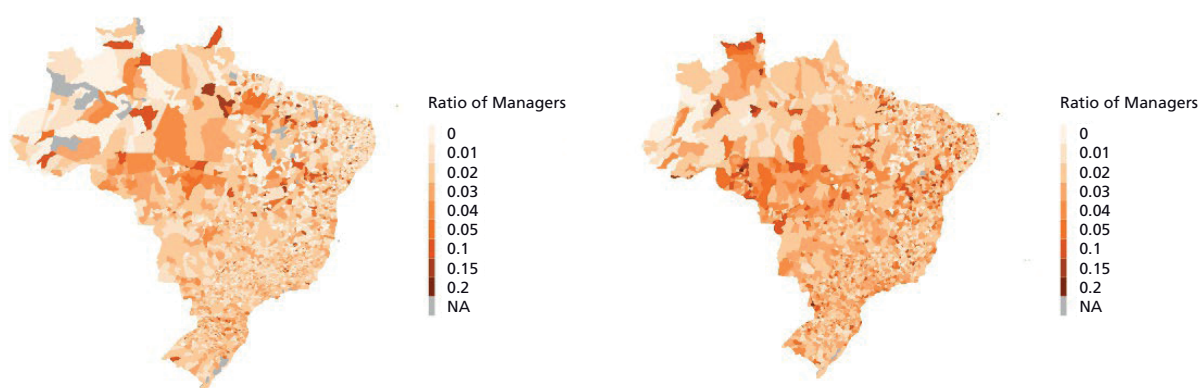
The share of managerial positions is the main variable of interest, and its representation across the country is illustrated in figure 2. These maps show the heterogeneity of this variable distributed across municipalities throughout the country and how these heterogeneity behave over time. For the label, a division into levels was made, with 0 being the lowest and 0.2 the highest. The choice of values was made through a consultation of the most frequent values. Among these, 0.02 is the most frequent level, meaning municipalities with between 1% and 2% of managers in their formal workforce are more common and that fewer and fewer cities have null observations for this occupation. The purpose of map 1 is to demonstrate that the variable of interest in the study is comprehensive across the country and that its evolution over time is heterogeneous.

MAP 1

Share of managerial positions in municipalities

1A – 1999

1B – 2006



Source: MTE (1999; 2001; 2005; 2006).

Obs.: The map and its municipal contours were drawn using the R package geobr. For the year 1999 we used the map referring to the municipalities from the 1991 census and 2006 referring to the 2001 census. The NA's are derived from inconsistencies between municipalities listed in RAIS and in the package. The number of observations for 1999 is 4526 and 5563 for 2006. The levels of proportion of managers were based on a histogram and the most frequent were chosen. 0 means zero observations, 0.01 represents observations from 0 to 0.01 and so on. Observations after 0.2 are not as frequent as the others and are therefore not part of the map.

Table 2 illustrates the development over time of the mean and standard deviation of the number of employees in general, by sector and municipality, as well as the corresponding quantities for each type of position included in the group we call the high-level hierarchy.

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We observe that both the average number of total employees and the average number of managerial employees increase over the eight years. In particular, the average number of managerial employees in 2006 (10.4) is more than double the average in 1999 (4.9). The table also shows the evolution of the average number of employees in each of the components of managerial positions: managers only, directors only, and executives only. This growth applies to all these more detailed groups. It is important to note that the “executives only” category shows a much lower number in the first two years than in the last two years, probably due to classification differences that were not accounted for in the conversion from CBO 1994 to CBO 2002. However, this is not an issue when using aggregate data for all managerial positions because the “managers only” group includes most of the managerial positions, which is the primary variable of interest. Nevertheless, it would be a problem for a disaggregated analysis focusing only on this smaller group of workers, so we will not conduct such an analysis in this article.

The bottom of table 2 shows some aggregates from our sample, which starts with about 23 million workers in 1999 and grows to 36 million workers in 2006, the final year of the analysis. When aggregated into cells by sector and municipality, however, the number of observations increases from about 73,000 in 1999 to about 105,000 in 2006. This increase is mainly due to the growing number of municipalities, as shown earlier in this section.

TABLE 2**Descriptive table of the main dependent variables**

	1999		2001		2005		2006	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total Workers	320,4	1888,9	340,9	1998	345,09	2333,5	350,81	2469
Management Roles	4,92	57,01	5,43	70,87	10,51	102,35	10,42	109,03
Only Managers	4,55	53,37	5,06	66,63	9,65	94,43	9,56	10,1
Only Directors	0,35	4,97	0,35	5,32	0,59	9,08	0,6	9,1
Only Executives	0,009	0,66	0,009	0,69	0,27	5,24	0,26	4,7
Observations	73.647		77.881		97.032		105.329	
All Workers	23.230.605		26.127.770		33.485.053		36.950.582	

Source: MTE (1999; 2001; 2005; 2006).

Obs.: The observations correspond to an interaction of municipality and sector for each year of the study. Total workers represent the number of individuals in the selected sectors before aggregation. Directors are identified by code 14 in the CBO, executives by code 13, and managers by code 12; all these positions are considered managerial roles.

3.2 Technological Intensity

For the definition of technology-intensive sectors, this study follows a strategy used by Almeida, Corseuil and Poole (2018). In broad terms, the authors follow the calculation of sectoral technological intensity proposed by Oldenski (2014) for the United States and adapt it to the Brazilian sectoral classification.

The detailed construction of this measure can be described as follows. In 2003, the CPS, American census, published a supplementary survey in which one topic questioned whether individuals used a computer at work, so Oldenski (2014) calculated the share of workers using a computer per occupation and then developed a sector indicator with this share weighted by the number of workers in each occupation. This variable is defined as technological intensity and was calculated for the sectors based on the classification provided in the United States.

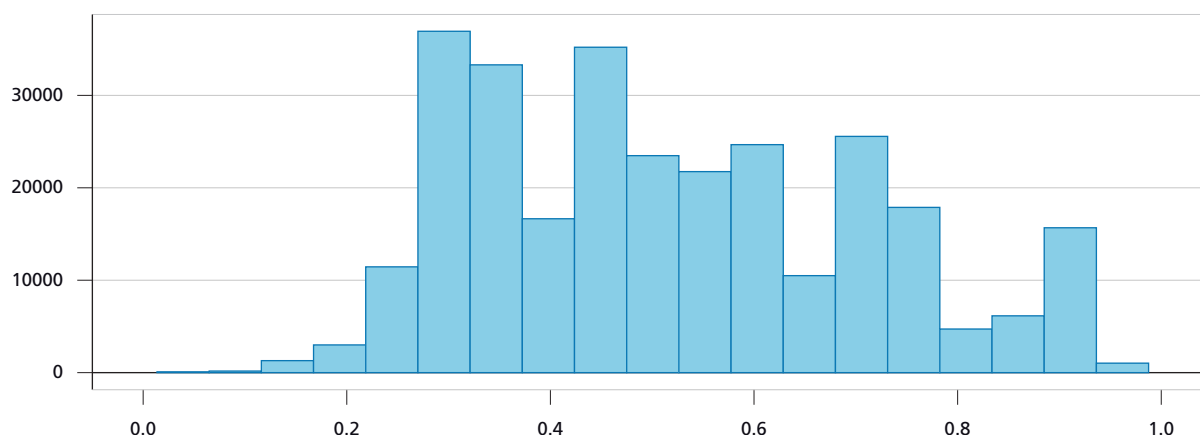
The CNAE 1.0 follows international standards, allowing for conversions with other activity classifications, such as the North American Industry Classification System (NAICS). This study uses the conversion performed by Muendler (2002), who conducted a detailed study of both classifications for precise conversion.

Figure 2 below shows a frequency histogram of the technological intensity variable used. A reasonable spread of values can be observed. There are relatively high frequencies around an intensity of 0.4. Another interesting detail is the asymmetric behavior in the tails. While the frequencies to the left of this value drop sharply, the same does not happen to the right, where some frequency peaks can be observed around 0.7 and 0.9, for example.

In some empirical exercises, high intensity is defined in this study as occurring when the observed value for a given sector is greater than the median of the intensity distribution across sectors of activity in Brazil.

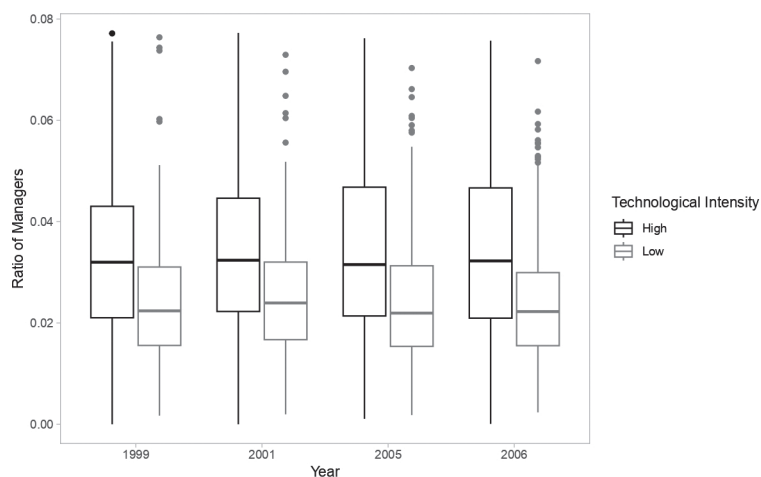
The following box-plot shows the evolution of the share of top managers in sectors, classified with 4 digits according to CNAE 1.0, with high and low technological intensity. For descriptive purposes, the proportional variable used in this figure refers to sectors, unlike the proportional variable in the regression, which refers to sector and local integration. Outliers have been excluded from the graphs. It is possible to analyze that a higher ratio of managerial positions is more common in high-intensity sectors than in low-intensity sectors, and for the former there is an evolution mainly in the third quartile.

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FIGURE 2**Histogram of the technological intensity variable**

Source: MTE (1999; 2001; 2005; 2006); CPS, 2003.

Obs.: The technological intensity follows Almeida, Corseuil and Poole (2018). The departure point is Oldenski (2014) method for the United States. Adaption to Brazilian industries goes as suggested Muendler (2002).

FIGURE 3**Share of managerial positions per year in high and low-tech sectors**

Source: MTE (1999; 2001; 2005; 2006).

Obs.: We aggregated the share of managerial positions to 4 digit sectors by CNAE code and year, resulting in a total of 1932 observations. The technological intensity follows Almeida, Corseuil and Poole (2018). The departure point is Oldenski (2014) method for the United States. Adaption to Brazilian industries goes as suggested Muendler (2002). High intensity is defined when the observed value is greater than the median, in this case greater than the average of the sectors observed each year. Outliers are not included in this figure.

3.3 Internet Provision

Since the privatization of Telebrás, a large state-owned communications company, Brazilian cities have experienced rapid growth in internet access. This happened in 1998. A year later, the annual municipal survey, MUNIC, investigated the presence of a private internet service provider in cities. In addition to 1999, this question was asked in 2001, 2005 and 2006. In the database, the variable is represented as a dummy, where 1 indicates the presence of internet in that year.

Figure 4 shows two scenarios of internet penetration by private operators in the country. The first map represents the year 1999, one year after the privatization of Telebrás, while the second one is for the year 2006, the last one used in the panel of this study. It can be seen that the internet gradually reached the municipalities, but it was present in all regions of the country from the beginning.

There is a significant evolution in the number of municipalities with internet coverage over the 8-year period, with a leap from 18.21% coverage in 1999 to 45.60% in 2006, illustrated in the figure by the increase in the intensity of the green color. It can be said that the maps do not show any specific geographical concentration of internet access. However, the hypothesis that exogenous factors are responsible for the timing of the arrival of the Internet in different municipalities will not be adopted.

Table 3, on the other hand, displays the differences in the share of workers between cities with and without internet service in the given year, between high- and low-intensity sectors, and the interaction of these dimensions. In all the years studied, cities with internet access have a higher share of workers in high hierarchical positions. There is an annual trend in cities with internet, again with the exception of 2006, while there is no consistent pattern in cities without internet.

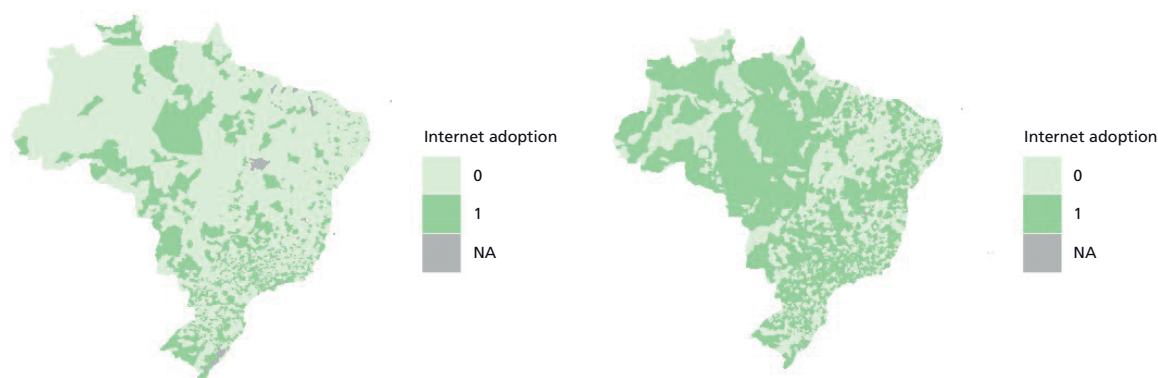
The interaction between high technological intensity and cities with internet shows that after the proportional increase from 1999 to 2005, there was a decrease in the last year. Meanwhile, for the interaction between low-intensity and cities without internet, the last two observed years show higher proportions than the initial years. The proportion of more technological interaction is higher than that of less technological interaction, following the same direction as the other descriptive statistics.

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FIGURE 4**Trends in internet coverage through private services in municipalities**

4A – 1999

4B – 2006



Source: IBGE (1999; 2006).

Obs.: The map and its municipal contours are drawn using the R package geobr. For the year 1999, we used the map referring to the municipalities in the 1991 census, and for 2006 we used 2006. The NA's are derived from inconsistencies between the difference in period between the MUNIC survey and the census, as well as from municipalities that refused to answer the survey. Without NA's, 1999 has 4469 observations and 2006 has 5558 observations.

TABLE 3**Descriptive table of the dependent variables in technology-intensive and non-technology-intensive cities**

Year	1999	2001	2005	2006
Municipalities with internet service	0,0161	0,0165	0,031	0,0301
Municipalities without internet service	0,0101	0,0091	0,0194	0,0191
High technology intensity with internet	0,0194	0,0206	0,0334	0,0324
Low technology intensity sector without internet	0,0101	0,0091	0,0194	0,0191

Source: MTE (1999; 2001; 2005; 2006).

Obs.: The table shows the share of managerial positions in different years and categories of municipalities. Data on the presence of Internet services in the city are provided by MUNIC. The technological intensity follows the strategy of Almeida, Corseuil and Poole (2018), which uses the calculation of Oldenski (2014) for the United States and adapts it to Brazilian industries, as proposed by Muendler (2002). High intensity is defined when the observed value is greater than the median.

4 EMPIRICAL STRATEGY

To examine the impact of Internet growth on the hierarchical structure of firms relative to sectors with different levels of technology, the triple difference model was used. This strategy is based on the hypotheses that: i) the technological shock affects industries differently depending on their technological intensity; and ii) this difference at the sectoral level is constant across municipalities. The main equation to be estimated is

$$Y_{rit} = \beta_0 + \beta_1(Adoption_{rt} * USE_i) + \beta_2 Adoption + \rho_{ri} + \delta_{Ist} + X_{rit} + \epsilon_{rit} \quad (1)$$

The municipalities are identified by r , time by t , s for the 27 states of Brazil, i represents industry at a 4-digit level, and l at a 2-digit level. $Adoption$ is a dummy indicating 1 for each municipality with internet service in that period. Technological intensity is defined by the variable USE . The dependent variable Y_{rit} represents the ratio of high hierarchy workers.

In addition to these explanatory variables, we include two sets of fixed effects: the first, denoted by ρ_{ri} , captures unobservable characteristics such as sectoral leadership practices or municipal development that may influence the proportion of high-level hierarchy workers. The second fixed effect δ_{Ist} is a categorical dummy interaction between industries at the two-digit level (l), states (S), and time, aimed at capturing regional changes that may have occurred during this period.

Note that unlike the adoption variable, USE does not have its own coefficient because the effect is thought to be present in the fixed effect ρ_{ri} .

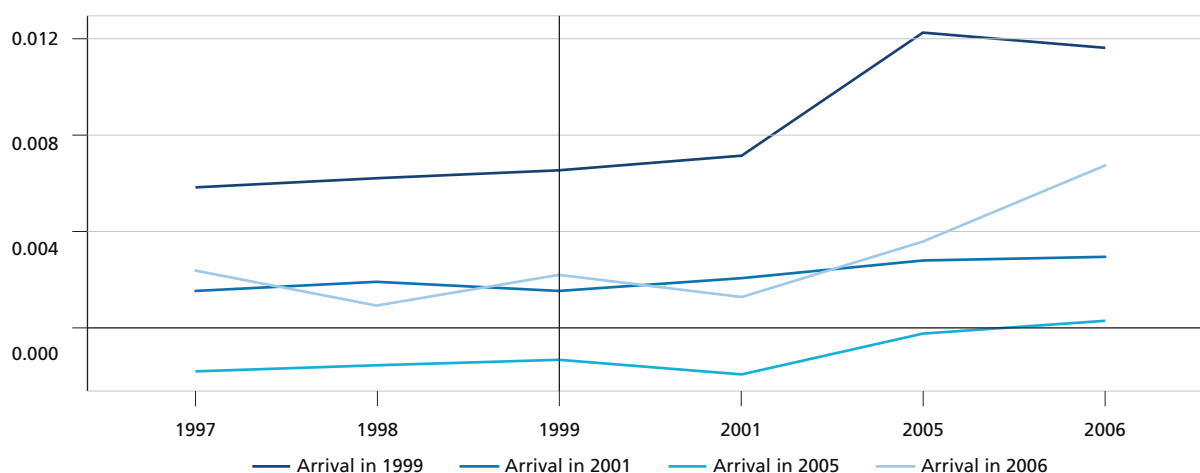
Finally, X_{rit} is a vector of controls such as GDP, city size, education level, share of experienced and novice workers, and import/export ratios. The GDP data used in this study refers to the annual municipal GDP provided by IBGE. Similarly, the city size variable is based on annual population estimates for each municipality, also provided by the IBGE. For educational level, we use the proportion of workers with secondary education by municipality, and the same approach is used to categorize experienced and novice workers. Experienced workers are defined as those with more than ten years of work experience, while novice workers are those with up to 5 years of work experience. In terms of import and export ratios, we consider the value of imports and exports moving through each city as a share of the country's total annual import and export volume.

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A typical difference-in-differences model considers different time periods and distinguishes between a treated group and a control group (Angrist and Pischke, 2009). In this approach, the analysis would consider the treated group as those communities that received internet access and examine this effect on occupations in industries without distinguishing by level of technological intensity. The main hypothesis of this specification would be that the ratio of managerial positions would evolve steadily across municipalities before or independent of internet access. However, this is a very strong assumption that is difficult to meet. Figure 6 shows trends in the ratio of managerial positions in municipalities since 1997. The group in which the internet was not available until 2006 is excluded from the graph and serves as a reference for the other groups. These are represented by the difference between their values and the values of the group that did not yet have internet access. The solid blue line intersects the y-axis at 0, and the dashed gray line shows the first year in which the treatment can be identified. The graph shows that there is no pattern of parallel trends in the years before the treatment.

FIGURE 6

Ratio of managerial positions in municipalities according to the arrival of the internet



Source: MTE, 1997; 1998; 1999; 2001; 2005; 2006.

Obs.: Each line represents a proportion of managerial positions in different categories of cities. The continuous line represents urban areas where, until 2006, the internet had not been introduced. The other lines indicate the areas where the arrival of the internet was identified in 1999, 2001, 2005 and 2006.

Alternatively, we opted for triple differences, a less restrictive model considered as the difference between two differences-in-differences (Olden and Møen, 2022).⁵ This methodology allows for trends in the ratio of managerial positions to be distinct prior to the shock, in municipalities where the internet arrived early, late, or not at all. However, it is assumed that this difference remains constant between groups, in this case, technology- intensive and non-technology-intensive sectors. In this paper, technological intensity represents the third layer, categorized according to Oldenski (2014) methodology. It is understood that the hypothesis is met because, in the absence of treatment, all the unobserved factors that determine the evolution of managerial positions differently across municipalities affect the sectors equally. Equation 2 demonstrates the hypothesis this work attempts to meet.

$$\begin{aligned}
 & E(\Delta Y_{0rit} | \text{Adoption}_{rt} = 1, \text{USE}_i = 1) - E(\Delta Y_{0rit} | \text{Adoption}_{rt} = 1, \text{USE}_i = 0) \\
 & \quad = \\
 & E(\Delta Y_{0rit} | \text{Adoption}_{rt} = 0, \text{USE}_i = 1) - E(\Delta Y_{0rit} | \text{Adoption}_{rt} = 0, \text{USE}_i = 0)
 \end{aligned} \tag{2}$$

Considering Y_{0rit} the proportion of workers in high-level hierarchy occupations in a counterfactual scenario where there is no internet arrival, $\text{Adoption} = 1$ for municipalities that received internet service, $\text{USE}_i = 1$ for high-intensity sectors and 0 for low-intensity sectors.

From the satisfaction of the hypothesis demonstrated in equation 2, the main coefficient to be analyzed is β_1 , which corresponds to the impact of internet provision for technology-intensive sectors relative to the impact of internet provision in non-technology-intensive sectors.

In order to validate the strategy used, a placebo test was conducted to examine the behavior of the share of managerial positions in cities before the shock. The placebo test consists of a cross-sectional regression of the proportional change in the proportion of managers between 1999 and 1997, the period before the technological shock. The equation is as follow:

$$\begin{aligned}
 \Delta Y_{ri99} = & \beta_0 + \sum_t (\beta_{1t} \text{Adoption}_{rt} * \text{USE}_i + \beta_{2t} \text{Adoption}_{rt}) + \delta_{Is} + X_{ri99} \\
 & + \Delta \epsilon_{ri99}
 \end{aligned} \tag{3}$$

5. Triple differences were first introduced by Gruber (1994), who categorized a group of married women into those aged 20 to 40 and those aged 40 or older to estimate the impact of maternity leave on wages.

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ΔY_{ri1999} represents the difference in managerial employees between 1999 and 1997. The explanatory variables without the subscript “t” represent observations from the year 1999, and dummies for the following years, 2001, 2005 and 2006, have been included, identifying the first year of private internet provision in the city according to the MUNIC research, represented by the sum of “t”, where $t = 1999, 2001, 2005, 2006$. The main purpose of including these dummies is to analyze whether the timing of a city’s access to the internet influenced the share of managerial positions before the technological shock. The omitted category consists of cities that did not have internet access in 2006. All controls from equation 1 that refer to the year 1999 were used. In this specification, the only effect is the categorical dummy for government and industry CNAE 1.0 at two digits.

5 RESULTS

Tables 4 and 8 show the estimation results of equation 1. In addition to the main outcome, the ratio of top managers, the analysis also regressed the three occupations that together make up this variable: the ratio of managers and directors. We avoided conducting an exercise with the proportion of executives due to the low number of workers detected in this category, as well as the susceptibility of this category to changes in the CBO classification.

The first table is the standard fixed effects regression, while the second table includes the remaining controls. As discussed in the previous section, β_1 is the coefficient identified by the triple difference methodology and corresponds to the effect of the arrival of internet services in technology-intensive industries relative to the arrival of the internet in non- technology-intensive industries.

We observe that the coefficient β_1 is positive and significant in all cases. The positive sign of our coefficient of interest indicates that the arrival of the Internet tends to favor the employment of managers (or positions at the top of the hierarchy) in technology-intensive sectors. According to the theoretical framework on which we base our analysis, this result suggests that the benefits of the Internet as a communication tool tend to prevail as the technological intensity of the sector increases.

By occupation, the largest effect is associated with the manager position, suggesting that it is the occupation with the greatest ability to moderate the main coefficient.

TABLE 4**Internet growth on in managerial employment in tech-intensive sectors**

	All top management employees	Managers	Directors
	(1)	(2)	(3)
<i>Adoption * USE</i>	0.046*** (0.002)	0.044*** (0.002)	0.002*** (0.0002)
<i>Adoption</i>	-0.021*** (0.001)	-0.02*** (0.001)	-0.001*** (0.0001)
All fixed effects	YES	YES	YES
Other controls	NO	NO	NO
Observations	348,817	348,819	348,821

Source: MTE (1999; 2001; 2005; 2006); IBGE (1999; 2001; 2005; 2006).

Obs.: Columns (1), (2) and (3) refer to the model without controls for the dependent variables, respectively, all senior management workers, only managers and only directors according to the CBO. The coefficient identified by the empirical strategy is Adoption * USE; *** 1% significance; ** 5% significance; * 10% significance.

Controls included GDP, city size, educational attainment, proportion of experienced/novice workers, and import/export ratios. These variables could affect firm organization at the industry, regional, and annual levels. An exercise was conducted to add each control one at a time to confirm the robustness of the variable, and it was observed that the control with the greatest significance was the proportion of experienced workers. In addition, it was found that large and developed cities and the percentage of workers with a high school education have an opposite effect on the proportion of top managers. Observations with a high import ratio have a positive effect on the dependent variable, while exports have the opposite effect. Table 5 shows the coefficients after adding all controls, and does not change significantly.⁶

It is important to note that when performing the occupational conversion provided by the CBO, some observations are marked as NA. When analyzing the occupations with missing data, 8 managerial positions were identified and removed, while the remaining observations were classified as non-managerial. The proportion of managers is calculated by dividing the number of managerial positions by the total number of employees in each observation unit. As a test, a regression was run excluding all missing observations, and the results showed no significant difference.

6. For robustness, this specification was tested using comparable minimum areas instead of municipalities. The results did not show significant changes.

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TABLE 5

Internet growth on in managerial employment in tech-intensive sectors with controls

	All top management employees	Managers	Directors
	(1)	(2)	(3)
<i>Adoption * USE</i>	0.039***	0.037***	0.002***
	(0.002)	(0.002)	(0.0002)
<i>Adoption</i>	-0.018***	-0.017***	-0.001***
	(0.001)	(0.001)	(0.0001)
All fixed effects	YES	YES	YES
Other controls	NO	NO	NO
Observations	348,817	348,819	348,821

Source: MTE (1999; 2001; 2005; 2006); IBGE (1999; 2001; 2005; 2006).

Obs.: Columns (1), (2) and (3) refer to the model without controls for the dependent variables, respectively, all top management workers, only managers and only directors according to CBO. The controls used were GDP, city size, proportion of workers with secondary education, proportion of experienced and novice workers, proportion of imports and exports for each observation sector, municipality and year. The coefficient identified by the empirical strategy is Adoption * USE; *** 1% significance; ** 5% significance; * 10% significance.

In order to verify some heterogeneity, we performed regressions on different groups of cities: those with more than 100 thousand inhabitants, those with less than 100 thousand, 25 thousand and 10 thousand inhabitants, as shown in table 6.

TABLE 6

Management positions in municipalities of different sizes

	Over 100 thousand	Under 100 thousand	Under 25 thousand	Under 10 thousand
	(1)	(2)	(3)	(4)
<i>Adoption * USE</i>	-0.004	0.037***	0.040***	0.062***
	(0.006)	(0.002)	(0.003)	(0.007)
<i>Adoption</i>	0.003***	-0.017***	-0.018***	-0.028***
	(0.003)	(0.001)	(0.002)	(0.004)
All fixed effects	YES	YES	YES	YES
Other controls	YES	YES	YES	YES
Observations	138,736	207,788	81,583	25,050

Source: MTE (1999; 2001; 2005; 2006); IBGE (1999; 2001; 2005; 2006).

Obs.: The coefficient identified by the empirical strategy is Adoption * USE; *** 1% significance; ** 5% significance; and * 10% significance.

The model validation, the placebo test, yielded non-significant results, as illustrated in table 7. The Adoption variables and their corresponding years indicate whether the municipality had internet provision identified for the first time by MUNIC during that period. For instance, Adoption 2001 equals 1 for municipalities that had not adopted internet by 1999 but did so at some point before 2001. The omitted category consists of municipalities that did not have private internet service by 2006. These variables are used to differentiate municipalities that promptly or belatedly adopted this digital service. This dummy variable was also interacted with technological intensity for specific years.

TABLE 7
Placebo results

	All top management employees
AdoptionxUSE 1999	0.003 (0.002)
AdoptionxUSE 2001	-0.001 (0.003)
AdoptionxUSE 2005	-0.003 (0.003)
AdoptionxUSE 2006	-0.003 (0.007)
Adoption 1999	-0.002* (0.001)
Adoption 2001	0.0001 (0.002)
Adoption 2005	0.001 (0.002)
Adoption 2006	-0.0001 (0.004)
Observations	65,028

Source: MTE (1997; 1999); IBGE (1999; 2001; 2005; 2006).

Obs.: This refers to the placebo specification using all senior management workers as the dependent variable. The controls used were city size, proportion of workers with secondary education, proportion of experienced and novice workers, proportion of imports and exports of municipality. The variables Adoption and the corresponding year refer to whether the municipality had internet provision identified for the first time by MUNIC in that period.

Note¹: The variable Action*USE is the dummy interacted with technological intensity for the specific years.

6 CONCLUSION

This paper analyzes whether task reallocation among works is more intense in sectors that are more likely to be affected by new technology. We can say that wage inequality is influenced not only by the within-sector component, but also by its between-sector component. Based on the notion that increased internet coverage in municipalities benefits firms digitally, the triple difference method was used to determine how this growth strengthened the upper hierarchy, represented by the ratio of managers, executives, and directors.

The privatization of Telebrás in 1998 allowed Brazilian municipalities to experience a rapid growth of private internet services. This circumstance began to be studied by the MUNIC Municipal Research in 1999, and this study showed descriptively that the arrival of the internet occurred comprehensively throughout the country until 2006.

We find that there is a positive and significant relative effect of internet adoption on top-tier employment by industry, municipality, and year. In the presence of firm fixed effects and a categorical dummy for state and sector, the effect for technology-intensive sectors is 0.046 without additional controls and 0.039 with their addition. In isolated occupational specifications, the managerial position is the most important moderator in the main specification, with an effect of 0.044 without controls and 0.037 with controls. The other position, director, show modest effects confirming the protagonist role of the managerial position in this specification. These results support the theory that communication enhances the managerial role, as proposed by Bloom et al. (2014), and suggest the dominance of the impact of communication over information with the advent of the internet.

In terms of other heterogeneity, there is a positive and significant result for cities with less than 100 thousand inhabitants, in contrast to cities with more than 100 thousand inhabitants. This result becomes stronger as the number of inhabitants decreases. This suggests that the technological shock affects managerial positions more in smaller cities. The placebo test yielded statistically null results for all coefficients, confirming the identification hypothesis. This indicates that the trends in the share of managers in intensive and non-intensive sectors prior to the technological shock occurred similarly in municipalities where the internet arrived early and late, as identified by the year dummies and their interactions. This test provides a basis for interpreting the results in the context of the triple difference model.

Following Almeida, Corseuil and Poole (2018), who used the same shock, this paper contributes to the literature on technological labor market effects, focusing on managerial occupations. There isn't much evidence on the relationship between organization and digital progress in developing countries, so this work, by using data from Brazilian formal labor records, is considered an empirical advance in this aspect.

In addition to the various effects of technological progress on the labor market that have been explored in this literature over the years, the way in which firms organize themselves also emerges as a concern. Bloom et al. (2014) show that communication empowers decision makers, a role typically played by a manager, while depriving non-managerial workers of autonomy. Our results indicate that the arrival of the internet led to a relatively higher increase in the ratio of managers in sectors that tend to use this technology more. This finding suggests that, at least for these sectors, the communication dimension was the one that most affected Brazilian firms. This is a policy concern simply because managers earn higher salaries, suggesting a preference for wage inequality. On the other hand, an increase in the role of managerial positions suggests that some individuals in the labor market are experiencing career advancement. This raises the possibility of future empirical advances in analyzing the role of information technology among non-managerial workers, as a more informed worker is a worker with more autonomy.

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