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Periodical Part

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Wage returns from telework in Brazil: an analysis based on the concept of potential telework

Abstract: In recent years, another form of performing work activities has been growing and attracting attention in Brazil, especially after the COVID-19 pandemic: telecommuting. Our study proposes to estimate the wage returns of potential telecommuting in Brazil, under the hypothesis that teleworkers earn more than those who do not work remotely. To achieve our goal, we used two data sources (PNADC/IBGE and ANATEL) to build a pooled data over the years 2018-2023. Since telecommuting can be correlated with the individual's innate ability, estimates by the 2SLS regression using variables instruments were adopted. Generally, the results showed that, for the sample analyzed, telecommuting individuals received, on average, 20.3% more in their usual weekly wages. We use COVID-19 as an instrumental variable – because of its exogeneity, which has never been explored in literature. We also used the definition of Potential Telework occupations as a measure to telework.

Keywords: Telecommuting; Telework; Remote Work; Home Office; Wage differentials.

Classificação JEL: J31; J81; C26.

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1. Introduction

Telecommuting has emerged as a viable alternative for many organizations and professionals in Brazil, allowing work activities to be carried out remotely (see Góes *et al.*, 2020) for a definition of Telework and Table 2 for data on Telework). The precise definition of telecommuting may vary, but generally, it refers to the performance of professional tasks in a home environment. Telework is widely recognized as a work strategy that promises to provide substantial benefits, such as increased worker control over the location and timing of their tasks, as well as reduced commuting time, associated costs, and environmental pollution.

Dingel and Neiman (2020) show that this type of occupation has grown substantially in recent years. In a list of 85 countries, Luxembourg had the highest proportion of telework, with 53.4%, while Mozambique recorded the lowest share, with only 5.24%. Brazil ranked 45th in this ranking, with a telework rate of 25.65%, considering the twelve Latin American countries. When we consider only the Latin American countries, Brazil came in third place, very close to Chile, which recorded a rate of 25.74%, and behind Uruguay, which led the list with a share of 27.28% in telework.

Data for Brazil show that, between 2018 and 2023, the number of individuals who reported working from home increased from 9,024 to 15,480, an increase of 71.53% (see Table 2). Since the number of people working remotely has been growing over the last few years and there are no studies in Brazilian literature analyzing the impact of this type of activity on wages (mainly due to a lack of data), the analysis of wage differentials becomes an important issue, especially in the current socioeconomic landscape, which has been affected by the COVID-19 pandemic.

COVID-19 caused a sudden transformation in labor markets (Barrero; Bloom; Davis, 2020), initially depressing and then increasing business formation rates (Haltiwanger, 2020a), followed by high job reallocation rates after the pandemic and driving a major shift that favored working from home (Bick *et al.*, 2020; Brynjolfsson *et al.*, 2020; Ozimek, 2020). Existing analyses of this sudden transformation investigate only whether the relative employment growth was merely a persistent reallocation shock favoring companies with high Work From Home (WFH) capacity to the detriment of companies with low WFH capacity.

Therefore, much has been discussed about the consequences of the pandemic, but little has been explored regarding these consequences, especially in the context of the role of telework, which is the focus of our study. Thus, the main objective of this research is to analyze the wage returns of potential telework in Brazil. Since the COVID-19 pandemic is an exogenous event and highly correlated with telework, it was used in the identification strategy of this paper.

However, databases that monitor telework in Brazil over the years are scarce, which poses some difficulties in identifying the effect. The only databases that contain individual-level information on what could be considered telework in Brazil are the Continuous National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios Contínua* - PNADC/IBGE) and the PNAD COVID19, conducted only in 2020. Due to its broader temporal scope, we opted to use the PNADC, although with some limitations: instead of considering telework itself, we considered 'potential' telework.

To identify individuals in potential telework, we used the methodologies developed by Dingel and Neiman (2020) and Góes *et al.* (2020). The method developed by Dingel and Neiman (2020) maps potential telework in the United States of America and 85 other countries. Based on the Occupational Information Network (O*NET) survey, the authors classify occupations as likely or unlikely to be performed through *home office*. The great advantage of working with this methodology is that it aligns with the International

Standard Classification of Occupations (ISCO-08). This labor occupation structure is widely used by several research institutes around the world, including Brazil. It plays a crucial role in guiding the Household Occupation Classification (COD) used in the PNADC and other surveys conducted by the Brazilian Institute of Geography and Statistics (IBGE) (Góes *et al.*, 2020; Martins *et al.*, 2021). Thus, although they have distinct occupations, the structures of these classifications present similarities that allow their reconciliation with the classification of occupations adopted in the PNADC.

To estimate wage returns, we used pooled data from 2018 to 2023 and the identification model of Mincer (1974) and Glass and Noonan (2016). To address the endogeneity problem of the telework variable, we used the instrumental variables method, exploring the role of the pandemic and the role of the internet as determinants of telework. Based on this, we show that individuals who work from home, with or without a dedicated workspace, earn, on average, higher wages than those who perform their work in other locations designated by the company.

For a better understanding of the issue studied, this paper is structured into three additional sections, beyond this introduction. Sections 2 and 3 summarize the main existing studies on telework, not exclusively analyzing its effect on wages, and the conclusions they reach. In section 4, we discuss the methodology used, the data sources, and the instrumental variables. In section 5, we present the descriptive statistics of the sample used and the results. Finally, we present the conclusion of the paper.

2. Literature review

As remote work continues to gain prominence, it is important to examine the impact of telework on wages (Choukir *et al.*, 2022). Although there are numerous benefits to working remotely, such as greater flexibility and the elimination of the need for commuting (Kelliher and Anderson, 2010; Rhee, 2008), reduced work-family conflict, employee satisfaction, and commitment to the company (Baltes *et al.*, 1999; Dubrin, 1991; Hill *et al.*, 2003), the relationship between telework and wage returns is not clear.

Studies on productivity related to telework show a positive association between this mode of work and workers' earnings. Glass and Noonan (2016) and Heywood *et al.* (2007) highlight that remote work can result in wage gains, especially for female teleworkers. However, the company's sector in this wage increase must be considered, as pointed out by Schroeder and Warren (2005).

'Smart-working' has been the subject of study, with Angelici and Profeta (2023) discussing its impact on worker productivity and well-being. Results from a randomized experiment showed that this approach increases productivity and improves work-life balance, especially for women. These studies highlight the importance of flexible work practices, such as telework and 'smart-working,' in helping companies adapt to crises like the coronavirus pandemic (Maestas *et al.*, 2023).

Another relevant aspect is the impact of sleep on productivity, as demonstrated by Gibson *et al.* (2018). An increase in average weekly sleep is positively associated with increases in workers' earnings, highlighting the importance of this factor in maximizing worker utility. Additionally, studies on working from home over time reveal a significant evolution in the wage effects of this practice, shifting from a wage penalty to a wage premium. Oettinger's (2011) study highlights the importance of changes in occupational distribution and the reduction of home-based wage penalties in explaining these gains, emphasizing the relevance of changes within occupational groups to understand trends in this context.

Bloom *et al.* (2015) conducted a study at CTrip International Corporation aimed at investigating the impact of working from home on call center employees' performance

and satisfaction. The methodology adopted involved a 9-month experiment in which 503 volunteer employees were randomly divided into home and office work groups, observing the effects over this period. The results indicated a significant 13% increase in the performance of home-based workers, driven by a 9% increase in hours worked and a 4% increase in calls per minute. Additionally, home-based employees showed greater job satisfaction and reduced turnover.

The study conducted by He *et al.* (2021) highlights the value placed on work flexibility by workers, especially in jobs with telework options. The results indicate that workers prefer jobs offering flexible schedules and locations, and are willing to accept lower wages in exchange for this benefit. Moreover, the research suggests that, under certain circumstances, workers value flexibility in work more than higher wages, demonstrating the relevance of this aspect in job choice (Choukir *et al.*, 2022).

Mas and Pallais (2017) emphasize the importance of considering heterogeneity in workers' valuations of different job characteristics. The researchers point out that analyses based solely on averages of Willingness to Pay (WTP) can be misleading, highlighting the need to understand individual variations in workers' preferences. Additionally, the research reveals that, although schedule flexibility is not widely valued by most workers, a significant portion of the workforce is willing to accept lower wages in exchange for options like working from home, indicating the existence of potential compensatory wage differentials in the market.

The organizational literature suggests that the negative wage returns from telework are more related to workplace norms and expectations than to actual productivity or the ability to offer flexibility (Konrad and Yang, 2012). Managers value 'face time' as an indicator of commitment, and limiting time on-site by working from home signals questionable job commitment to employers (Glass; Noonan, 2016). Teleworkers may face a serious 'flexibility bias' in the evaluation of their competence and commitment, even when evaluators were informed that senior managers also work remotely.

Organizational signaling theory suggests that the consequences of deviating from the ideal worker norms may not be gender-neutral (Glass; Noonan, 2016; Felfe, 2012; Goldin, 2014). The stigma placed on workers, disproportionately women, who openly display family care responsibilities can contribute to reduced earnings directly through evaluation bias and indirectly through the assignment of less important tasks (Kmec *et al.*, 2014). Negative stereotypes about competence, productivity, and workplace commitment are activated more by motherhood than by fatherhood, which can affect women and mothers who work remotely (Correll *et al.*, 2007). Men avoid asking for family accommodations to avoid being 'feminized' and punished at work (Vandello *et al.*, 2013). Since the signaling function of telework is not as strong for men, women and mothers may suffer more negative wage consequences from telework than men.

Kleven *et al.* (2019) investigate the impact of children's arrival on gender inequality in the Danish labor market. The authors highlight that the arrival of children creates a long-term gender gap in earnings, strongly influencing women's labor market participation, hours worked, and wage rates, while men are unaffected. Additionally, they identify that the fraction of gender inequality related to children has significantly increased over the past decades, accounting for about 80% of gender inequality in 2013. On the other hand, Gimenez (2019) examined the effect of telework on workers' well-being during work, focusing on gender differences. The results revealed that male teleworkers reported significantly lower levels of stress, pain, and fatigue compared to male workers who commute. No statistically significant differences were found between female teleworkers and female workers who commute.

Although there is extensive literature on telework and its effects on wage returns, there is no clear consensus on the impact of remote work on these returns. Some of the

literature points to a positive relationship between telework and wages, while another part suggests that some workers are willing to accept lower wages in exchange for greater flexibility at work. Additionally, when analyzing wage differentiation by gender, a persistent stereotype about women exists, although some studies do not find any significant effect in this regard. Therefore, it is necessary to conduct a more robust analysis of this phenomenon, using stronger empirical methodologies, and it is crucial to carry out a specific analysis for the Brazilian labor market

3. Telework in Brazil

Telework, also known as remote work, has gained increasing attention in various countries, including Brazil. The COVID-19 pandemic accelerated the adoption of these practices in several countries, including Brazil (Mishima-Santos *et al.*, 2021). However, in the Brazilian context, the implementation of telework faces limitations within organizations, with specific issues that need to be considered (Junior *et al.*, 2020).

The pandemic has highlighted the existing inequalities in remote work in Brazil, bringing attention to workforce disparities (Castro & Moreira, 2021). Studies have examined the impact of telework on different groups in the country. For instance, research has focused on the effects of telework on university professors during the pandemic, highlighting changes in work intensity and routines (Boehs, 2023). Additionally, the well-being of Brazilian teleworkers has been a subject of study, emphasizing the importance of task design and clarity in sustaining well-being (Latorre *et al.*, 2021). Telework management practices in Brazil have also been analyzed, particularly in companies that were not accustomed to this modality before the pandemic (Figueira *et al.*, 2023).

In the literature, the analysis of potential and actual telework has gained attention (see Baltes *et al.*, 1999; Dingel and Neiman, 2020; Guntin, 2020; Martins *et al.*, 2021). Martins *et al.* (2021) explain the difference between the estimated potential for remote work and actual remote work in Brazil. They estimate the telework potential based on the Dingel and Neiman (2020) methodology applied to Brazil's Continuous PNAD survey (PNADC), with data collected before the COVID-19 pandemic. They then compare this potential with the remote work measurement provided by the COVID-19 PNAD survey, conducted between May and November 2020. Using Dingel and Neiman's (2020) adapted methodology for the PNADC, they found that 22.7% of national occupations had the potential to be performed remotely, a 9.4 percentage point difference from what was observed in May (the maximum remote work point calculated via the COVID-19 PNAD) and a 13.7 percentage point difference in November.

International literature also identifies a difference between potential and actual telework. For the United Kingdom, the telework potential was 43.5%, while actual remote work ranged between 38% and 20%, depending on the month of the survey, as highlighted by Dingel and Neiman (2020). This shows a discrepancy between the estimated potential and the actual. Martins et al. (2021) identify some possible causes for this difference in Brazil, including inadequate infrastructure and a lack of clear regulations for remote work.

Góes *et al.* (2020) analyze the feasibility of potential telework during the COVID-19 pandemic in Brazil using the Classification of Occupations for Household Surveys (COD). The author finds a positive correlation between the percentage of telework and per capita income, with significant variations between states in the Federation and types of occupational activities.

Later, Góes *et al.* (2022) refine the evidence and show that 24.1% of the total employed population in Brazil has the potential to perform their activities remotely, representing around 20.4 million people. The effective income of people with telework

potential exceeds the usual by 9%, and these people account for about 40% of the total income. The results also show that 58.3% of people in potential telework in Brazil are women, while 60% are white. These results are similar across the country's macroregions, with predominant age ranges between 30 to 39 and 20 to 49 years, representing about 30% of the total people in potential telework.

In Brazil, the distribution of specialized human resources in remote regions has proven to be a challenge, possibly due to the lack of attractiveness of these areas for work. Additionally, the country's large population and significant levels of poverty have influenced remote work configurations, making it crucial to consider political and poverty issues in telework implementation. Overall, remote work in Brazil presents both opportunities and challenges. While it may increase flexibility and well-being for some workers, it also highlights issues of inequality, resource distribution, and the need for effective management practices adapted to the Brazilian reality.

Based on the evidence presented above, it is essential to conduct empirical research that investigates not only the specific aspects of telework but also the relationship between telework and remuneration, as well as the effect of the pandemic on earnings, to support adequate and evidence-based wage policies, ensuring the success and sustainability of telework agreements in the country.

4. Empirical analysis

4.1. Data source and sample construction

To achieve the proposed objective, we used microdata from the Continuous National Household Sample Survey (PNADc) of the Brazilian Institute of Geography and Statistics (IBGE) over the period 2018-2023. Since this is a survey with a rotation scheme for interviews that leads to repeating households over several quarters, some precautions were taken to avoid duplicating observations when we pooled the data.

In the PNADc rotation scheme, the household is interviewed once per quarter and remains in the survey for 5 consecutive quarters, with a 2-month interval between interviews. For example, if the household was interviewed in the 1st quarter of year X, it will be interviewed again over the next 4 quarters, meaning until the 1st quarter of year X+1. Therefore, in the 2nd quarter of year X+1, this household will not appear[5].

The choice of which quarters to pool is justified in two ways: 1) individuals who reported in the interview that they worked from home only began to appear significantly from 2018; 2) the last quarter published, up to the present moment of this study, was the 1st of 2023. Thus, following what has been stated and the IBGE rotation scheme 1(5) to avoid duplication of information, the following quarters were pooled:

Table 1 - Selected quarters of each year.

Quarter	Year
4	2018
1	2019
2	2020
3	2021
4	2022
1	2023

Source(s): Self-elaboration by the authors.

For sample selection, we considered employed individuals with a formal job related to their main work, living in urban areas, and aged over 16 years (as established by the Federal Constitution of Brazil). We excluded workers in the public sector, temporary employees, military personnel, employers, retirees, and pensioners. In addition to these

[5] For further information, please confer: https://www.ibge.gov.br/arquivo/projetos/sipd/segundo_forum/segundo_amostra.php#:~:text=O%20esquema%20de%20rota%C3%A7%C3%A3o%20%C3%A9,repetindo%20esse%20esquema%205%20vezes.

strategies, based on the work of Góes et al. (2020) and Martins et al. (2021), we selected only individuals in occupations that can be performed remotely, using the Classification of Occupations for Household Surveys (COD) from the PNADc.

Table 2 - Classifications of occupations eligible for telework.

Variable V4010 – PNADc
1111, 1112, 1113, 1114, 1120, 1211, 1212, 1213, 1219, 1221, 1223, 1321, 1322, 1323, 1324, 1330, 1344, 1345, 1431, 2111, 2120, 2133, 2142, 2151, 2152, 2153, 2161, 2162, 2163, 2164, 2166, 2265, 2266, 2310, 2320, 2330, 2341, 2342, 2351, 2352, 2353, 2354, 2355, 2356, 2359, 2411, 2412, 2413, 2421, 2422, 2424, 2431, 2511, 2512, 2513, 2514, 2519, 2521, 2522, 2523, 2529, 2611, 2612, 2621, 2622, 2631, 2632, 2633, 2634, 2636, 2641, 2643, 2651, 2652, 2653, 2654, 2655, 2656, 2659, 3118, 3311, 3312, 3313, 3314, 3315, 3321, 3322, 3323, 3341, 3342, 3343, 3352, 3353, 3359, 3411, 3413, 3421, 3422, 3423, 3511, 3512, 3513, 3514, 3522, 4110, 4120, 4221, 4222, 4223, 4225, 4311, 4312, 4313, 4411, 4413, 4415, 5165, 5241, 5244, 5311, 5312, 7316, 7317, 7318, 7319 e 7533.

Year	Quarter	Telework				
		0		1		
		Quant.	%	Quant.	%	Total
2018	4	460.643	98,08%	9.024	1,92%	469.667
2019	1	461.220	98,01%	9.361	1,99%	470.580
2020	2	465.063	97,89%	10.016	2,11%	475.078
2021	3	464.401	96,86%	15.045	3,14%	479.446
2022	4	467.051	96,57%	16.612	3,44%	483.664
2023	1	469.008	96,80%	15.480	3,20%	484.487
Total		**2.787.385**	**97,36%**	**75.538**	**2,64%**	**2.862.923**

Note: Workers considered in "telework" are those who, during the PNADC interview, responded that the location where they performed their activities was "At the residence, in a space dedicated exclusively to work" and "At the residence, without a space dedicated exclusively to work" (Variable V4022). Data replicated using the calibrated weight provided by PNADC (Variable V1028).
Source(s): Goés *et al.* (2020); Self-elaboration by the authors based on PNADC/IBGE data.

However, it is worth noting that the estimated wage returns for potential telework using Dingel and Neiman's (2020) classification may lead to overestimations, as their classification assumes a productive structure typical of an advanced country, which may not be fully prevalent in Brazil. In addition to this limitation, the methodology proposed by the authors assumes that the same occupation can be performed remotely regardless of the company's activity, which may not always be true. Despite these limitations, we believe that considering only these occupations is better than considering all, since the PNADc is one of the few databases that contains information on telework (see Guntin, 2020; Martins *et al.*, 2021). Therefore, our study used the COD to define occupations whose tasks could be performed remotely.

Lastly, it is important to note that we opted to include only companies without a physical location/establishment. It is believed that, in such cases, the worker has fewer options for choosing where to work, thus mitigating a possible selection bias (which could occur if the worker had the option to negotiate between working at the company's establishment or remotely from home).

4.2. Empirical specification: 2SLS and IV

To analyze how telework influences workers' wages, a more appropriate empirical strategy would be to use panel data to control for fixed effects and reduce potential omitted variable bias in the telework variable. However, given the data limitations and the chosen wage determination model (which is largely composed of variables that do not change over time), we opted to use the Ordinary Least Squares (OLS) method with pooled data. Table 3 describes each of the variables that will be used in the model. All variables are sourced from PNADC.

Table 3 - Variables used in the estimations.

Dependent variable	Description	Variable code
Real weekly hourly wage **ln(*wagehour*)**	Usual monthly earnings from the main job divided by hours worked during the reference week. Values are adjusted to constant prices of the first quarter of 2023 (using the deflator provided by IBGE for the PNADC).	VD4016/V4039
Variable of interest	**Description**	**Variable code**
Telework **(*dtele*)**	1 = if the work was usually performed at the residence, with a dedicated space for the activity (or not); 0 = otherwise.	V4022
Control variables	**Description**	**Variable code**
Gender ***(gender)***	1 = female; 0 = male.	V2007
Age ***(age)***	Age (years).	V2009
Age² ***(age2)***	Age squared (years).	V2009
Education level ***(yearseduc)***	Years of study.	VD3005
Race/ethnicity ***(color)***	1 = brown or black; 0 = white or yellow	V2010
Marital status ***(maritalstatus)***	1 = married; 0 = single.	V2005
Number of children ***(numchildren)***	Number of children and stepchildren per household	V2005
Area type ***(larea)***	1 = Capital; 2 = Rest of the Metropolitan Region (*RM*, excluding the capital); 3 = Rest of the Integrated Development Region (*RIDE*, excluding *RM* and capital); 4 = Rest of the Federation Unit (*UF*, excluding capital, Metropolitan Region and Integrated Development Region).	V1023
Time employed in the main job ***(ltimejob)***	1 = Less than 1 month; 2 = From 1 month to less than 1 year; 3 = From 1 year to less than 2 years; 4 = 2 years or more.	V4040
ln*(population)*	Population projection for the quarter by geographic levels (reference: middle month).	V1029

Source(s): Self-elaboration by the authors based on the PNADC/IBGE dictionary.

Based on the wage model by Mincer (1974) and Glass and Noonan (2016) and the previous table of variables, the estimated equation assumed the following specification:

$$\ln\left(\text{wagehour}\right)_{i,t} = \alpha + \beta_1 \text{dtele}_{i,t} + \beta_2 \text{dtelepand}_{i,t} + \rho \text{X}_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $Y_{i,t}$, is the natural logarithm of hourly wages for individual *i*, in year *t*; $Tele_{i,t}$ is the telework variable of interest, equal to 1 if the individual works from home, and 0 otherwise; Another variable of interest is $dtelepand_{i,t}$, which is the interaction between the telework binary variable and the pandemic binary variable[6]; $X_{i,t}$, is a vector of measurable characteristics that are expected to affect wages, including years of education, marital status, age, age squared, race/ethnicity, gender, and area. These variables are commonly included in studies of wage returns.; β_1, β_2 and ρ are the coefficients, and $\varepsilon_{i,t}$, is standard errors clustered by occupation eligible for telework.

One of the factors that may influence potential telework is innate ability. If this issue is not addressed, it could cause bias associated with the omission of a relevant variable in equation (1)'s model. Considering that ability is an intrinsic characteristic of individuals and cannot be measured or controlled through a proxy, one way to mitigate this problem, which can be implemented, is the use of instrumental variables, which we will explain later.

4.3. Instrumental variables

Ordinary Least Squares (OLS) estimates are biased when an important variable is omitted. In this study, the variable considered endogenous is telework, as it may be correlated with innate ability. One way to address this issue is by adopting instrumental variables. However, for an instrument to be considered valid, it must not be correlated with the error term and must be correlated with the endogenous explanatory variable (i.e., it must be relevant) (Wooldridge, 2010).

A first instrument we adopted in this study was the COVID-19 pandemic. According to the literature (see Barrero, Bloom, & Davis, 2020; Barrero *et al.*, 2021; Haltiwanger, 2020b), COVID-19 pandemic had negative effects on the entire global economy. The shutdown of multiple economic activities, combined with the need for social distancing measures, resulted in a substantial decrease in consumption and investment levels. As

[6] The pandemic variable is a binary variable that equals 1 from the first quarter of 2020, and 0 otherwise. Based on Brazilian Legislative Decree No. 6 of 2020. Available at:https://www.in.gov.br/en/web/dou/-/decreto-legislativo-249090982. Acesso em: 04/03/2023.

a direct consequence, there was a significant increase in unemployment and economic inactivity, accompanied by a reduction in working hours (Avdiu & Nayyar, 2020; Béland *et al.*, 2020; Corseuil *et al.*, 2021).

We justify the use of this variable as an instrument due to its clear correlation with telework (since, with the adoption of social distancing measures and lockdowns, many workers began to work remotely) and, importantly, because it is an exogenous event. Furthermore, as many workers transitioned to working from home, we believe there was no direct effect on wages, but rather a restructuring of work activities that was reinforced by government measures to mitigate the effects of COVID-19 on the labor market (such as the Emergency Benefit for Employment and Income Maintenance – BEM, which was adopted by the Brazilian government).

Another instrumental variable we used was Broadband. More specifically, we used the "Average Contracted Internet Access Speed (Mbps)" by municipality, provided monthly by the National Telecommunications Agency (ANATEL), and the "Composition of Metropolitan Regions, Integrated Development Regions, and Urban Agglomerations" from 2021 made available by IBGE. Through these variables, we constructed the average speed by area (Capital, rest of the Metropolitan Region, rest of the RM, and rest of the State) to make this data compatible with the PNADC.

Regarding its role as an instrument, we justify it by its lack of correlation with innate ability (which is an omitted variable in the model) and its likely correlation with telework (areas with greater internet access may be associated with a higher number of teleworkers, as the latter depend on the former to work remotely). Furthermore, we believe that this variable does not interfere, at least not directly, with wage levels. Table 4 below summarizes these variables.

Table 4 - Instrumental variables used for telework.

Instrumental variable	Description	Variable Code	Source
COVID-19 pandemic ***(dpand)***	1 = yes; 0 = no.	UPA, Estrato, V1008, V1014, V2005.	PNADC
Average contracted broadband speed ***(avaragespeed)***	Average broadband internet speed by area in megabytes for the quarter.	-	ANATEL

Source(s): Self-elaboration by the authors.

Since we used two instruments, one of which is clearly exogenous, it was possible to conduct tests such as the overidentification restriction test to analyze whether the second instrument is valid. To assess whether these instruments are relevant for explaining telework, we analyzed the joint F test of the instrumental variables used for the endogenous variable of interest (i.e., the F test for the excluded instruments). Additionally, we estimated a series of other tests, described in the following table:

Table 5 - Validity tests of the instruments.

Test	Null hypothesis	Should I reject?
Kleibergen-Paap rk LM Statistics	H_0: The model is underidentified.	Yes (p value <0,10)
Hansen J Statistics	H_0: The instruments are valid, meaning they are not correlated with the error term, and the excluded instruments are correctly excluded from the estimated equation.	No (p value >0,05)
Endogeneity test	H_0: The specified endogenous regressor can indeed be treated as exogenous.	No (p value >0,05)
Kleibergen-Paap Wald F Statistics	H_0: The instruments are weak.	Yes (p value <0,10)
Anderson-Rubin Wald; Stock-Wright LM S Statistics	H_0: The coefficients of the endogenous regressors in the structural equation are jointly equal to zero, and the overidentification restrictions are valid.	No (p value >0,05)

Source(s): Self-elaboration by the authors.

5. Results

5.1. Descriptive statistics

For this descriptive analysis, we considered the sample data without applying weights, since, as a large portion of the variables is binary, the attempt to apply weights assigned continuous values to these data. Moreover, the software used for most of the tables and graphs does not support the application of weights of the same type used in the OLS and 2SLS estimates. Therefore, our analysis refers to the data after applying all the filters highlighted in Section 4.1.

Tables 6 and 7 report basic statistics for the continuous and discrete variables used in the model, considering each of the areas (regions) provided in the PNADC. As can be observed, most of the observations come from the capital cities, followed by the remaining municipalities in the states. The smallest portion of observations comes from the Integrated Development Regions (*Regiões Integradas de Desenvolvimento Econômico* – RIDE), which is to be expected, as most Brazilian states do not have a RIDE. For the "*wagehour*" variable, the regional disparity is evident between municipalities in areas 1 and 2 and those in the interior (area 4). As for years of education and age, in the sample analyzed, the areas showed very similar average values, with the smallest representation being from individuals living in the rest of the RIDEs.

Table 6 - Summary of continuous variables.

Area	Variable	Obs	Mean	Std. Dev.	Min	Max
1 - Capital	wagehour	450	124,72	132,9302	18,94	1022,78
	age	450	37,05	11,5075	16	71
	yearseduc	450	14,33	2,3347	0	16
	population	450	4.860.959	4.187.523	296.563	12.505.526
2 - Rest of RM (excluding the capital)	wagehour	138	101,88	127,91	27,8	1.217,08
	age	138	35,43	9,45	19	61
	yearseduc	138	13,16	3,23	0	16
	population	138	4.179.826	3.311.846	125013	9781544
3 - Rest of RIDE (excluding RM and capital)	wagehour	2	32,07	1,51	31	33,13
	age	2	54,5	4,95	51	58
	yearseduc	2	12,5	0,71	12	13
	population	2	139513.5	40714,5	110724	168303
4 - Rest of UF (excluding RM, capital and RIDE)	wagehour	426	83,42	70	24,47	452,6
	age	426	35,52	10,02	16	64
	yearseduc	426	13,26	2,4	1	16
	population	426	7970653	6474563	164955	24.912.844

Note: The variable "wagehour" is obtained on a weekly basis and has been deflated using the usual deflator provided by IBGE for the PNADC. RM - Região Metropolitana; RIDE - Região Integrada de Desenvolvimento Econômico; UF - Unidade de Federação..
Source(s): Self-elaboration by the authors based on the research results.

For the *dummy* variables, most workers are not in telework (except in the capitals), are men (except in the capitals), are white or Asian (except in the RIDEs), and are married. Regarding the other variables, most of our sample has been with their main employer for 2 years or more, and the number of children varies significantly across areas: in the capitals, most workers have no children, while in the metropolitan regions (*Região Metropolitana* – RM), the majority have at least one child. For the two individuals representing the RIDEs in the sample, both have two children. In the rest of the states of Brazil, most workers have only one child.

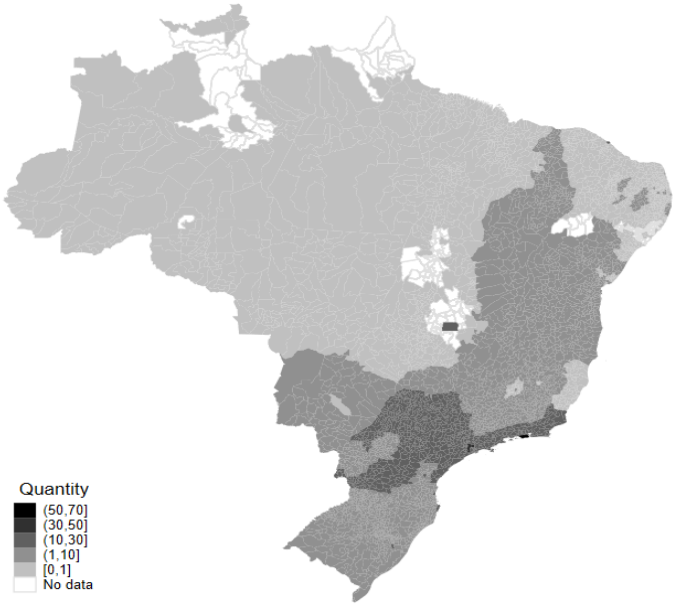
Table 7 - Summary of discrete variables.

Variable/value		Area type								Total
		1		2		3		4		
		Quant.	%	Quant.	%	Quant.	%	Quant.	%	
dtele	0	216	48,00%	78	56,52%	2	100%	290	68,08%	586
	1	234	52,00%	60	43,48%	0	0%	136	31,92%	430
gender	0	258	57,33%	89	64,49%	2	100%	290	68,08%	639
	1	192	42,67%	49	35,51%	0	0%	136	31,92%	377
color	0	253	56,22%	80	57,97%	0	0%	267	62,68%	600
	1	197	43,78%	58	42,03%	2	100%	159	37,32%	416
maritalstatus	0	338	75,11%	107	77,54%	2	100%	319	74,88%	766
	1	112	24,89%	31	22,46%	0	0%	107	25,12%	250
ltimejob	1	5	1,11%	4	2,90%	0	0%	4	0,94%	13
	2	89	19,78%	28	20,29%	0	0%	94	22,07%	211
	3	67	14,89%	11	7,97%	0	0%	60	14,08%	138
	4	289	64,22%	95	68,84%	2	100%	268	62,91%	654
numchildren	0	168	37,33%	50	36,23%	0	0%	115	27,00%	333
	1	154	34,22%	49	35,51%	0	0%	183	42,96%	386
	2	99	22,00%	30	21,74%	2	100%	96	22,54%	227
	3	25	5,56%	8	5,80%	0	0%	25	5,87%	58
	4	3	0,67%	1	0,72%	0	0%	7	1,64%	11
	6	1	0,22%	0	0%	0	0%	0	0%	1

Source(s): Self-elaboration by the authors based on the research results.

It is useful to observe, through a map of Brazil, the distribution of teleworkers across the areas named in the PNADC. Between 51 and 70 individuals are concentrated in the capital of Rio de Janeiro, followed by 31 to 50 individuals concentrated in the capital of São Paulo and in the rest of the other municipalities of Santa Catarina (excluding the capital and metropolitan region). Between 11 and 30 workers are located in Fortaleza (CE), the rest of Rio de Janeiro (excluding the capital), the rest of the metropolitan region and other municipalities of São Paulo, the capital and the rest of the state of Paraná, in Florianópolis (SC), Porto Alegre (RS), and Brasília (DF). Between 2 and 10 teleworkers are found in the rest of the state of Piauí and Mato Grosso do Sul, in Natal (RN), in the capital and the rest of the state of Paraíba, in the capital and the rest of the metropolitan region of Pernambuco, in the capital and the rest of the states of Bahia and Minas Gerais, in the rest of the metropolitan regions of Paraná and Santa Catarina, in the rest of Rio Grande do Sul (excluding the capital), and in the rest of the municipalities of Mato Grosso do Sul (excluding the capital).

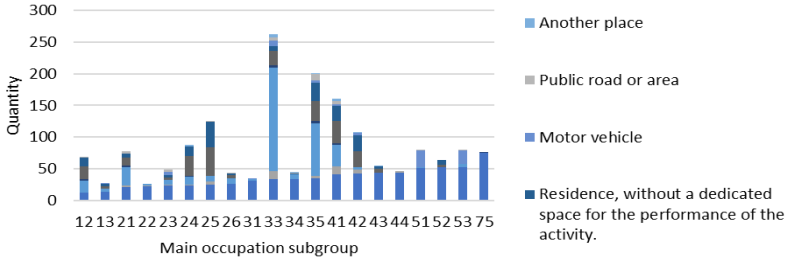
Figure 1 - Distribution of teleworkers.



Source(s): Self-elaboration by the authors.

We should also analyze the main occupational subgroups and divisions of the National Classification of Economic Activities (*Classificação Nacional das Atividades Econômicas* – CNAE) in the sample (Figure 2 and Figure 3). Most workers (whether in telework or not) are mid-level professionals in financial and administrative operations who work at a location designated by the employer, client, or customer. The smallest portion of our sample consists of executives and production and operations managers, as well as healthcare professionals. In all main occupational subgroups, there are individuals who work from their residence, without a designated workspace (likely working remotely).

Figure 2 - Number of workers by main occupation subgroup and workplace.



Main occupation subgroups:

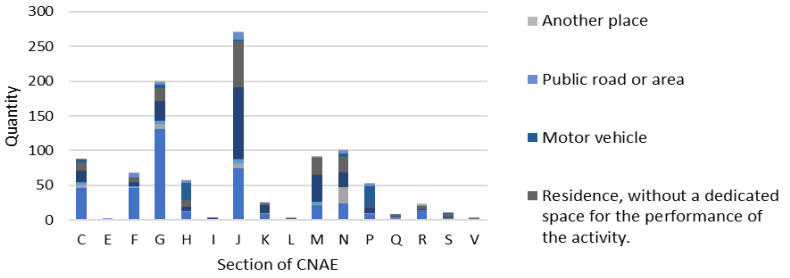
12 – Administrative and Commercial Managers
13 – Production and Operations Managers
21 – Science and Engineering Professionals
22 – Health Professionals
23 – Teaching Professionals
24 – Specialists in Public Administration and Business Organization
25 – Information and Communication Technology Professionals
26 – Legal, Social, and Cultural Professionals
31 – Associate Professionals in Science and Engineering
33 – Associate Professionals in Financial and Administrative Operations
34 – Associate Professionals in Legal, Social, Cultural Services, and Related Fields
35 – Information and Communication Technology Technicians
41 – Clerks
42 – Customer Service Workers
43 – Numerical Clerks and Material Recorders
44 – Other Administrative Support Workers
51 – Personal Services Workers
52 – Sales Workers
53 – Personal Care Workers
75 – Food, Wood, Garment, and Related Processing Plant Operators and Tradesmen

Source(s): Self-elaboration by the authors based on the research results.

For the activity divisions, we can observe that most workers are in the information and communication sector, followed by those in commerce, motor vehicle repair, and motorcycle repair. In both cases, the majority of individuals work in motor vehicles or from home (including those with or without a dedicated workspace for performing their activities). The smallest portion of individuals in our sample is in the sectors of "Water supply, sewerage, waste management, and remediation activities," "Accommodation and food service activities," "Real estate activities," and "Poorly defined activities.".

Thus, we can observe that the sample is well distributed among the occupations considered by Góes et al. (2020). Additionally, the activity sections (a broader grouping of the CNAE) in which the workers are distributed appear to be conducive to telework. Consequently, we believe that the sample is a solid database for estimating wage differentials, although it is acknowledged that there may be limitations regarding external validity.

Figure 3 - Number of workers by CNAE division and workplace.



Sections of CNAE (National Classification of Economic Activities):	M – Professional, scientific, and technical activities
	N – Administrative and support services
C – Manufacturing industries	P – Education
E – Water, sewage, waste management, and remediation activities	Q – Human health and social services
F – Construction	R – Arts, culture, sports, and recreation
G – Commerce; repair of motor vehicles and motorcycles	S – Other service activities
H – Transportation, storage, and postal services	V – Undefined activities
I – Accommodation and food services	K – Financial, insurance, and related services
J – Information and communication	
L – Real estate activities	

Source(s): Self-elaboration by the authors based on the research results.

5.2. Regression results

Since there is no consensus in the literature regarding the impact of telework on wages, our results will serve primarily as a preliminary guide for future studies in Brazil. However, based on the methodology adopted, we expect telework to have a positive effect on wages, especially considering that the demand for teleworkers in Brazil increased significantly due to the COVID-19 pandemic, and according to the law of supply and demand, this likely caused wages to rise.

We estimated eight models using OLS and 2SLS (two-stage instrumental variables), gradually adding control variables. However, to estimate the second stage of the 2SLS, we first needed to obtain the first-stage estimates to analyze the correlation between the instruments used and the endogenous variable of interest (*telework*). Table 8 contains the first-stage coefficients for each of the four second-stage regressions using the instrumental variables. We can see that the pandemic variable (*dpand*) is correlated with telework (*dtele*) in all the adopted specifications, as is the variable for average internet speed per municipality (*avaragespeed*). The F-test for the excluded instruments was above 10 in all specifications, indicating that the instruments are not weak. Therefore, it was possible to obtain second-stage estimates using these two variables as instruments for dtele. The results of the models (OLS and 2nd stage) are divided into two tables, Table 9 and Table 10.

Starting with Table 8, which disregards working time and population in all specifications, we observe that the estimates of *dtele* are quite close in both the OLS case and the second stage. Considering the other validity tests for the instruments, the *p*-values found indicate that model 4 is the most appropriate. In this model, *telework* demonstrated a positive effect on hourly/weekly wages; however, this effect was significant only at the 10% level.

Table 8 - First-stage estimates of 2SLS (Two-Stage Least Squares).

Variables	dtele			
	(1)	(2)	(3)	(4)
dpand	0,174**	0,174**	0,174**	0,175**
	(0,0773)	(0,0766)	(0,0756)	(0,0738)
avaragespeed	0,00133***	0,00129***	0,00126***	0,00126***
	(0,000254)	(0,000315)	(0,000315)	(0,000294)
gender	0,143**	0,143**	0,144**	0,133**
	(0,0551)	(0,0563)	(0,0553)	(0,0554)
age	-0,0238**	-0,0244***	-0,0239***	-0,0236***
	(0,00926)	(0,0087)	(0,00873)	(0,00869)
age2	0,000230**	0,000238**	0,000237**	0,000236**
	(0,000109)	(0,000102)	(0,000102)	(0,000103)
color	-0,0348	-0,0366	-0,0354	-0,00106
	(0,0369)	(0,0387)	(0,0385)	(0,0359)
yearseduc	0,0474***	0,0481***	0,0486***	0,0473***
	(0,0104)	(0,00998)	(0,00985)	(0,01)
maritalstatus	-0,0303	-0,0263	-0,0232	-0,0149
	(0,0471)	(0,0457)	(0,0445)	(0,0438)
numchildren	-0,026	-0,0241	-0,0215	-0,0258
	(0,0187)	(0,0186)	(0,0185)	(0,0187)
_larea_2		0,0897	0,092	0,115**
		(0,0568)	(0,0564)	(0,0541)
_larea_3		-0,0651	-0,0649	0,204**
		(0,0871)	(0,0856)	(0,0917)
_larea_4		-0,0292	-0,0294	-0,066
		(0,0699)	(0,0694)	(0,0737)
_ltimejob_2			-0,00617	0,00511
			(0,135)	(0,119)
_ltimejob_3			0,0288	0,0196
			(0,108)	(0,0895)
_ltimejob_4			-0,0263	-0,0321
			(0,133)	(0,117)
lnpopulation				0,0777***
				(0,0189)
Constant	0,00533	0,00562	-0,00212	-1,201***
	(0,25)	(0,268)	(0,282)	(0,356)
F-test of excluded instruments	50,06	23,41	34,04	33,55
Number of occupations (clusters)	79	79	79	79
Observations	1,016	1,016	1,016	1,016
R^2	0,289	0,295	0,297	0,315
F- test	39,4	41,74	40,8	42,55

Nota: Regressions estimated using calibrated weights provided by PNADc/IBGE.
*** p < 0.01, ** p < 0.05, * p < 0.1
Source(s): Self-elaboration by the authors based on the regression results.

In Table 10, which considers working time and population in all specifications, both second stages of specifications (6) and (7) passed the instrument validation tests. However, the p-values obtained for the Anderson-Rubin Wald and Stock-Wright LM tests were low, failing to reject the null hypothesis only at the 1% level. In this test, it is worth noting that the goal is not to reject the null hypothesis (the higher the p-value, the better). Thus, considering the significance levels of 5% or 10%, the tests do not pass. However, overall, the coefficients obtained from both OLS and the second stage were quite close,

indicating a good overall fit. In the case of this table, the estimated coefficients for the variable of interest, with significance levels ranging between 1% and 5%, were higher than those estimated in specifications (3) and (4) of Table 9.

Table 9 - Wage differential estimates for teleworkers (OLS and 2nd stage with IV).

Variables	ln(real weekly hourly wage)			
	(1)	(2)	(3)	(4)
	OLS	2SLS	OLS	2SLS
dtele	0,256***	0,327***	0,238***	0,203*
	(0,0865)	(0,116)	(0,0843)	(0,117)
gender	-0,242***	-0,254***	-0,254***	-0,248***
	(0,0802)	(0,0862)	(0,0818)	(0,0844)
age	0,0657***	0,0677***	0,0678***	0,0669***
	(0,0165)	(0,0154)	(0,0166)	(0,0153)
age2	-0,000592***	-0,000612***	-0,000627***	-0,000618***
	(0,000195)	(0,000184)	(0,000199)	(0,000185)
color	-0,139***	-0,136***	-0,151***	-0,153***
	(0,0443)	(0,0435)	(0,0405)	(0,0382)
yearseduc	0,127***	0,123***	0,119***	0,121***
	(0,0159)	(0,0178)	(0,0141)	(0,0169)
maritalstatus	-0,0802	-0,0750	-0,0925	-0,0950
	(0,0608)	(0,0610)	(0,0632)	(0,0624)
numchildren	-0,0375	-0,0348	-0,0359*	-0,0370*
	(0,0226)	(0,0214)	(0,0208)	(0,0199)
_larea_2			-0,140	-0,139
			(0,0876)	(0,0857)
_larea_3			-0,924***	-0,934***
			(0,101)	(0,114)
_larea_4			-0,168***	-0,173***
			(0,0594)	(0,0620)
Constant	1,155**	1,136***	1,343***	1,356***
	(0,449)	(0,432)	(0,410)	(0,387)
Kleibergen-Paap rk LM *p*-value		0,0002		0,0001
Hansen J *p*-value		0,0239		0,3202
Endogeneity test *p*-value		0,7562		0,6717
Kleibergen-Paap Wald F statistics		50,064		32,667
Anderson-Rubin Wald test *p*-value		0,0028		0,1597
Stock-Wright LM S statistics		0,0136		0,1562
Number of occupations (clusters)	79	79	79	79
Observations	1,016	1,016	1,016	1,016
R^2	0,345	0,344	0,356	0,356
F-test	43,71	40,3	46,37	50,92

Note: Regressions estimated using calibrated weights provided by PNADc/IBGE. Weekly hourly wage at constant prices of the 1st quarter of 2023. *** p < 0.01, ** p < 0.05, * p < 0.1
Source(s): Self-elaboration by the authors based on the regression results.

Overall, all results lead to the conclusion that, for the analyzed sample, workers who perform their primary job activities at home earn higher wages, even when controlling for other personal characteristics. This finding is reinforced by the R^2 statistics obtained from each of the methods used (OLS and 2SLS) for the same specification. If the results from each of the methods diverged significantly from each other, the R^2 would be negative, as the sum of the squared residuals of the independent variable would be greater than the total sum of squares.

Table 10 - Wage differential estimates for teleworkers (OLS and 2nd stage with IV).

Variables	ln(real weekly hourly wage)			
	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS
dtele	0,249***	0,246**	0,241***	0,245**
	(0,0845)	(0,118)	(0,0824)	(0,118)
gender	-0,259***	-0,258***	-0,261***	-0,262***
	(0,0805)	(0,0844)	(0,0813)	(0,0853)
age	0,0661***	0,0661***	0,0661***	0,0662***
	(0,0162)	(0,0149)	(0,0162)	(0,0150)
age2	-0,000625***	-0,000624***	-0,000623***	-0,000624***
	(0,000196)	(0,000183)	(0,000196)	(0,000183)
color	-0,156***	-0,156***	-0,144***	-0,144***
	(0,0395)	(0,0375)	(0,0453)	(0,0445)
yearseduc	0,115***	0,116***	0,115***	0,115***
	(0,0139)	(0,0169)	(0,0140)	(0,0169)
maritalstatus	-0,110*	-0,110*	-0,107*	-0,107*
	(0,0642)	(0,0633)	(0,0642)	(0,0633)
numchildren	-0,0461**	-0,0462**	-0,0479**	-0,0477***
	(0,0196)	(0,0189)	(0,0188)	(0,0181)
_larea_2	-0,158*	-0,158*	-0,150*	-0,150*
	(0,0849)	(0,0823)	(0,0814)	(0,0783)
_larea_3	-0,940***	-0,941***	-0,848***	-0,848***
	(0,104)	(0,115)	(0,126)	(0,124)
_larea_4	-0,174***	-0,175***	-0,188***	-0,187***
	(0,0595)	(0,0622)	(0,0688)	(0,0705)
_ltimejob_2	-0,238**	-0,239**	-0,235*	-0,235*
	(0,118)	(0,116)	(0,123)	(0,121)
_ltimejob_3	-0,272*	-0,272*	-0,275*	-0,275*
	(0,151)	(0,149)	(0,152)	(0,150)
_ltimejob_4	-0,111	-0,111	-0,114	-0,113
	(0,0976)	(0,0966)	(0,0976)	(0,0979)
lnpopulation			0,0271	0,0267
			(0,0332)	(0,0327)
Constant	1,630***	1,631***	1,215	1,218
	(0,417)	(0,394)	(0,739)	(0,749)
Kleibergen-Paap rk LM *p*-value		0,0001		0,0001
Hansen J *p*-value		0,2263		0,2224
Endogeneity test *p*-value		0,894		0,91
Kleibergen-Paap Wald F statistics		34,038		33,555
Anderson-Rubin Wald test *p*-value		0,0443		0,0418
Stock-Wright LM S statistics		0,0178		0,0102
Number of occupations (clusters)	79	79	79	79
Observations	1,016	1,016	1,016	1,016
R^2	0,364	0,364	0,365	0,365
F-test	39,17	52,12	35,93	47,06

Note: Regressions estimated using calibrated weights provided by PNADc/IBGE.
*** p < 0.01, ** p < 0.05, * p < 0.1
Source(s): Self-elaboration by the authors based on the regression results.

With the results in hand, if we consider the 'most appropriate' equation (that is, the one with the best estimates from the IV tests), we can conclude that individuals working remotely earn, on average, 20.3% more than those who are not working remotely (the base group), at a significance level of 10%. When considering the OLS coefficient for the same specification, this value is slightly higher: individuals working remotely earn, on average, 23.8% more than those who are not working remotely (the base group), at a significance level of 1%. It is important to note, however, that these estimates are only valid for the selected sample.

6. Conclusion

This article sought to investigate how telework, measured through individuals who report performing their activities from their home in occupations conducive to telework, affects their usual hourly/weekly wages. Specifically, our goal was to analyze whether there is a wage differential between those who work remotely and those who do not. Despite some disagreement in the literature, the finding that there is a wage differential (with individuals in telework earning more compared to those who do not work remotely) is consistent with studies by other authors, such as Baltes et al. (1999) and Glass & Noonan (2016).

Based on the most robust model (IV), we estimate that individuals in telework earn, on average, 20.3% more than those not in telework (the reference group), with a significance level of 10%. When considering a 1% significance level for some validity tests of the instrumental variables used (Anderson-Rubin Wald and Stock-Wright LM), we find a significant wage differential of 24.5% at a 5% significance level. Essentially, we can conclude that there is a positive wage differential for telework in the analyzed sample.

Thus, this study contributes to the literature on wage differentials in the labor market by providing the first evidence of the effects of telework on wages. For future studies, we suggest exploring other instrumental variables, as well as controlling for other public policies aimed at mitigating the effects of COVID-19 on the main variable analyzed (wages). This would enhance both the internal and external validity of the results.

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