

Economywide and Sectoral Impacts on Workers of Brazil's Internet Rollout

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Abstract

This paper is a study of the effect of Brazil's staggered Internet rollout between 2000 and 2014 on municipality employment and wages. The study uses a new, annual data set on Internet availability from the Brazil school census, with the assumption that the share of schools that have Internet access in each municipality reflects the general accessibility of Internet connections. These data are combined with Brazil's rich, matched employer-employee survey, which contains annual occupation and wage earnings information for all formally-employed workers in Brazil across all sectors, including primary, secondary, and tertiary industry groups. Contemporaneous and lagged effects are considered. The analysis finds that increased Internet access has no

statistically significant net effect on aggregate employment, and has a negative effect on average wages, with a reduction in measures of wage dispersion. Brazil's Internet rollout results in employment shifts from sectors with more limited expansion opportunities (wholesale and retail trade, public administration, and largely publicly-owned utilities, which jointly comprise almost half of the formal workforce in 2010) to sectors with more output expansion opportunities. The employment effects are positive and most pronounced in the manufacturing, transport and storage, finance and insurance, and hospitality industry groups. In the manufacturing sector, Internet access induces positive employment and wage effects in medium- and high-skill occupations.

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I. Introduction

Over the past decade, Latin American and Caribbean countries achieved strong growth and shared prosperity. Yet, as commodity tailwinds have receded, South American countries in particular face the challenge of securing and expanding these social achievements in a sustainable manner, namely based on productivity growth. Spurring firm-level productivity upgrading in ways that ensure shared prosperity has become a top priority for the region.

The growth implications of technology adoption are well understood. Productivity upgrading through creative destruction is the main driver of long-run per-capita income growth. This dynamic involves the commercialization of frontier technologies, the adoption of existing improvements in managerial and production technologies by firms, and the reallocation of resources across industries and across firms within industries (Aghion and Howitt, 2009, Comin and Ferrer, 2013).

The distributional impact of technology adoption is more complex. The existing literature suggests that the impact is ambiguous. On the one hand, technology adoption can lead to income inequality if the benefits are disproportionately appropriated by owners of physical capital or managers and high-skill workers able to implement new technologies, without sufficient benefit to low-income or less skilled workers. At the limit, specific types of technology adoption that substitute machines for labor can make certain categories of workers redundant and unemployable (see Acemoglu and Autor (2011) and the related large literature on automation and skill-biased technological change). For example, technology adoption has recently been associated with a decline in mid-skill occupations relative to low- and high-skill ones in the United States (Autor and Dorn, 2013).

On the other hand, automation and other forms of technology adoption may complement labor, decreasing variable costs and increasing productivity, thereby raising output in ways that lead to higher demand for labor and increased earnings (Autor 2015). Such types of technology adoption and catch-up innovation that generate higher productivity, employment and sales, when spurred by a competitive business environment, have been recently shown to be associated with a larger employment share of low-skilled and female workers by an empirical study of over 26,000 manufacturing establishments across 15 OECD and 56 developing countries (see Dutz, Kessides, O'Connell and Willig, 2012). This finding suggests more inclusive firm growth from innovation and technology adoption. The use of the internet and the presence of job training programs are shown in these data to make significant contributions at every stage of the flow from ideas to inclusive employment growth.² And in a recent theoretical task-based model where labor has

² The finding by Dutz, Kessides, O'Connell and Willig (2012) that new technology-adopting innovating firms have higher employment growth rates and employ a higher share of unskilled and female workers than non-innovating

a comparative advantage in more complex versions of automated tasks, Acemoglu and Restrepo (2016) demonstrate that although automation tends to reduce employment and the share of labor in national income, the creation of more complex tasks has the opposite effect. In an extension of their model to include workers of different skill levels, they find that wage inequality increases with increased automation and the creation of new complex tasks in the short-run, but low-skill workers gain relative to capital in the medium term to the extent that tasks become standardized and the productivity of low-skill workers increases over time as learning pushes their wages up.

The impacts of the adoption of digital technologies on employment—on total employment, on employment shifts across sectors, and by skill levels—are empirical questions. Brambilla (2017) expands the recent task-based models of technical progress and labor markets to allow for firm heterogeneity and wages that vary across firms, to derive a set of predictions of the impact of firm investment in ICT on employment and wages, depending on the skill types of workers. In her model, skilled workers can be combined with ICT, which increases their productivity and reduces the firm’s cost of production. The model allows for varying degrees of complementarity or substitution between ICT and skilled workers, while ICT and unskilled workers are always substitutes. Each task can be performed by skilled or unskilled workers, with the output of each task also being an endogenous choice. There is a fixed adjustment cost of investing in ICT, so not all firms decide to invest. Heterogeneity in productivity across firms is responsible for differences across firms in size, employment, skill composition, task complexity and ICT investment decisions. Skilled-augmenting productivity differences generate differences in the skill ratio and in task complexity across firms. Finally, rent-sharing wage schedules generate wages levels and skilled to unskilled worker wage ratios that vary across firms. The difference in the responsiveness of the wages of skilled and unskilled workers in reaction to an increase in firm profits generates differences in wage inequality across firms. Key model predictions that we explore concern within-firm changes due to ICT investments related to unskilled and skilled worker employment and wages. The effect of ICT investments on both unskilled and skilled employment is ambiguous. When a firm invests in ICT, output increases due to the reduction in variable costs, working through a reduction in prices. The increase in total output increases the output of all tasks, including both skilled and unskilled tasks. However, at the same time, three substitution effects operate against the employment of unskilled workers: fewer tasks are performed by unskilled workers as they are replaced by tasks employing ICT and skilled workers; the activity levels of unskilled/non-complex tasks are reduced in favor of the activity levels of the now less-expensive tasks employing ICT and skilled

firms does not establish that as a result of technology adoption the earnings of unskilled and female workers become higher, nor that their income growth is faster than the skilled, nor that some of them are caused to gain higher skills. That paper’s data did not permit these questions to be addressed.

workers, conditional on output; and output shifts to the firms that become relatively more productive due to their relatively more intense employment of both ICT and skilled workers. For skilled workers, while these three substitution effects work in their favor, a fourth substitution effect, namely the possibility of ICT replacing skilled labor, may work against them. On the other hand, ICT adoption may support increased skilled employment inasmuch as they are net complements at the level of task performance. So while the overall effects of ICT adoption on employment are theoretically ambiguous, sufficiently strong output effects can increase both skilled and unskilled employment, while likely substitution effects can increase the ratio of skilled to unskilled labor. Finally, wages may increase for both skilled and unskilled workers due to rent-sharing wage schedules.

These theoretical perspectives are a substantial aid in delineating the relevant empirical and policy issues surrounding the extent and incidence of recent and forthcoming technology-driven economic growth. For example, according to Pagés (2010), there has been a lack of dynamism in the creation and expansion of productive firms and the exit of unproductive firms within Latin American and Caribbean countries relative to advanced economies. Nonetheless, there likely remains substantial potential for the within-firm channel of productivity gains from technology adoption to be a driver of broader income and aggregate productivity growth, and for such effects to ultimately be magnified by spurring more inter-firm dynamism.³

The objective of this paper is to provide a better empirical understanding of the impact of digital technology adoption in Brazil on jobs, wage levels and wage inequality economy-wide and across skill levels and industry groups. Our analysis is enabled by novel data that detail the fact that in Brazil the internet was rolled out in a staggered fashion over time from 2000 to 2014 across different municipalities. We are able to categorize our analyses by the industry groups that are primary (agriculture, fishing and mining), secondary (manufacturing) and tertiary (including finance & insurance, real estate, transport & storage, utilities, construction, hospitality, wholesale & retail and public administration), as well as disaggregated by employment-skill terciles. We use comprehensive matched employee-employer longitudinal data and quantify aggregate effects of the introduction of internet access in municipalities on local industry clusters and labor markets.

³ In a related study, Song, Price, Guvenen and Bloom (2016) construct a matched employer-employee data set for US firms. They show that virtually all of the rise in earnings dispersion among workers is accounted for by increasing dispersion in average wages paid by the employers of these individuals – namely the increase in individual inequality can be accounted for mainly by increases in cross-firm inequality, while the overall earnings dispersion within firms did not increase. Ongoing work of theirs is exploring the extent to which the increase in cross-firm inequality in the US is driven by growing productivity differential across firms versus increased sorting (that firms over time have been employing workers from narrower skills groups, with some firms paying much higher average wages than before because their average worker quality has increased). We intend to replicate the Song et al. approach for Brazil as part of a separate research project.

The next section describes our novel data. Section III presents our empirical strategy and findings. A final section concludes, including a discussion of some relevant policy considerations. In summary, we find that economy-wide, internet adoption has no statistically significant net effect on aggregate employment and has a negative effect on average wages, with a reduction in measures of wage dispersion. The absence of economy-wide significant net employment effects masks important shifts in employment from sectors with more limited expansion opportunities—wholesale and retail trade, public administration and largely publicly-owned utilities that comprise almost half of the formal workforce in 2010—to sectors with more output expansion possibilities. Employment effects are positive and most pronounced in manufacturing, transport and storage, finance and insurance, and hospitality industry groups. Importantly, internet adoption in manufacturing industries is inclusive, with positive employment and wage effects across high and medium-skill workers.

II. Data

We combine the rich, comprehensive data from Brazil containing annual matched employee-employer records with annual municipality-level information on the availability of internet to investigate the effects of technology intensity on the labor market outcomes of workers.

Labor market metrics are derived from the **Annual Social Information Survey (RAIS)**, which contains annual wage earnings and occupation information for all formally-employed workers in Brazil in all sectors, including agriculture, manufacturing and services. Each record is comprised of annual employer-reported data on the firm's industrial classification and each worker's hours, earnings, hiring/dismissal dates (if applicable), occupational classification, education level and age. The RAIS data importantly contain identifiers for both workers and employing firms; that is, because this is a longitudinal data set both for firms and workers, we are able to analyze worker employment histories for the entirety of their duration in the formal sector within our sample period, and within and across firms, occupations, and industries. Using the RAIS microdata, we construct an annual municipality-level dataset that contains aggregate indicators of employment, wages, worker turnover (based on hires and fires), number of firms and firm size.

To map the internet rollout in Brazil, we construct a new data set based on answers to questions on internet availability from the **School Census**, an annual survey of all schools in the country. We use this seemingly unrelated data-source because other more common sources—such as official telecoms data, Census, household and ICT surveys—are either too recent or do not allow municipal level disaggregation. Official data on internet availability at the municipal level (ANATEL) are only available from 2007 onward, by which time most municipalities had access. PNAD, the Brazilian household survey, only allows for spatial disaggregation at the state level. TIC Empresa, a specific survey of internet use by households and firms,

only allows an even more coarse spatial disaggregation, at macro-region, and is available only from 2005 onward, well after the most important phase of internet rollout. These data are also repeated cross-sections, preventing us from following the same firm over time. Finally, Census data, which contain questions on internet availability at the household level, are only available for 2000 and 2010.

The School Census is an administrative record filed by all preschool, primary and secondary schools in the country, both public and private. Since 2000, the school level form has included a question on internet availability at the school. The question on internet access has been available in all rounds of the School Census since 2000. We aggregate the data at the municipal level, using the share of schools with internet access as a proxy for internet availability in the municipality. The reliability of this measure is based on the assumption that the share of schools that have internet access reflects general accessibility of internet connections, and that internet access is not discretely off and then on at the municipality, but rather changes continuously over time. Our results are robust to the alternative of defining internet access in a municipality as discretely on for the first year in which more than 10 or 25% of schools report internet access, but in our primary estimations we maintain the share measure as our principal regressor. Table 1 contains summary statistics of the combined data set.

Table 1: Summary statistics
Municipality-year variation

Variable	Mean	SD	Min	Max	Obs
Average firm size (employees)	21	30	1	5,313	77,749
SD of firm size	83	104	0	11,766	77,298
Total new hires	3,600	36,624	0	3,033,010	77,749
Total workers fired	3,187	33,022	0	2,839,354	77,749
Total employment	9,830	104,288	1	8,087,258	77,749
Average monthly wage (real R\$)	946	335	8.016	14,182	77,749
Share of schools with internet access	0.49	0.36	0	1	74,184

Note: Summary statistics based on RAIS employee-employer records aggregated by municipality and year. Internet access from School Census.

There are 5,574 unique municipalities across 14 years of data from 2000 to 2013, with the mean municipality-year observation having approximately 465 firms employing more than 9,000 workers with an average firm size of just over 21 employees. Figures 1 and 2 show municipalities that had internet connections in 1999 and 2009, respectively (note that these are descriptive, and are not representing our measure based on the Schools Census).

Figure 1: Internet connections in 1999



Source: IBGE National Atlas of Brazil

Figure 2: Internet connections in 2009



Source: IBGE National Atlas of Brazil

III. Empirical strategy and findings

As our empirical strategy, we use within-municipality variation in internet access over time to estimate measures of labor market dynamics in a standard difference-in-differences framework, given by:

$$(1) \quad Y_{i,t} = \delta_0 + \delta_1 Z_{i,t} + \delta_2 Z_{i,t-1} + \Gamma_i + \Pi_t + \varepsilon_{i,t}$$

Equation (1) relates the focal labor market metric in municipality i in year t measured at the end of each calendar year to internet infrastructure availability Z in the same municipality and year, and lagged year, conditional on vectors of municipality and year fixed effects in Γ_i and Π_t , respectively.

The coefficient δ_1 then gives the change in the outcome measure for a unit increase in internet access from the previous to the current year, conditional on the increase experienced in the previous year. Including this term alone, however, would not capture effects that may occur only through longer-term adjustments to prices or productivity. For this reason, it is also important to recognize that firms with market incentives will react to lower marginal costs from increased productivity and seek to raise their output. Depending on the competitive structure of their output markets, firms will be motivated and able to sell more at lower prices in reaction to their lower marginal costs. This is a critical force to take into account, as added output raises demand for labor quite apart from the substitution or complementarity effects between technology shifts and tasks handled by different categories of labor. To test whether this may be the case, we have added to the specification a one-year-lagged measure of internet access, $Z_{i,t-1}$, with these lagged effects captured in δ_2 . The coefficients δ_1 and δ_2 are additive, allowing us to interpret their sum as the cumulative effect on the focal outcome in the two-year span following an increase in internet access.

For our analysis below, all dependent variable outcomes are in natural logs, and internet access is measured as the fraction of schools that have an internet connection in the municipality. It is important to note that the difference-in-differences approach identifies only short-run effects occurring within the one-year or two-year frequency with which we observe changes in internet access in a municipality. That is, the coefficient δ_1 is interpreted to be the percent change in the outcome metric between year $t-1$ and t for a municipality with zero percent internet access in $t-1$ and 100 percent access in t . Our estimated effects are net of other channels through which improvements in internet infrastructure affect firms and local labor markets other than firm internet use *per se*. For example, the municipal upgrade can affect other local economic actors that interact with the firm: local competitors may become more efficient, or local customers or suppliers may become better informed, or the workforce may be exposed to more opportunities.

While we quantify the effects of internet infrastructure upgrading on the labor market experience of workers across the skill distribution using the approach described above, there are several caveats to the interpretation of the estimates. First, and most importantly, there are broader effects on the economy of this technology/infrastructure upgrading, presenting potential violations of the identifying assumptions in the DD framework; that is, those areas that saw greater internet access sooner may have been on different trajectories than those that saw later access to internet. Municipalities experiencing increases in internet access at different times may not satisfy the “parallel trends” assumption, or, stated otherwise, the timing of internet rollout may be correlated with time-varying unobservables. The most prominent of these unobservables is a latent demand for internet access, which we would expect to be higher in municipalities with high-wage, dynamic labor markets, high-productivity firms, and/or a concentration of knowledge- or technology-intensive sectors. For the majority of the metrics that we assess, this violation of the DD assumption would tend to bias our results positively, suggesting our approach will recover magnitudes larger than those that would be estimated absent this possible concern.

Municipality-level employment outcomes

We begin by estimating economy-wide indicators of workers’ labor market dynamics. Using the matched employee-employer dimension, we calculate new-to-firm hires and firm-specific separations to get an aggregate measure of employment churn across firms within a given municipality. We also estimate aggregate employment and wage effects and standard measures of wage inequality (the standard deviation of monthly wages, and the 75th-25th and 90th-10th wage percentile gaps).

Table 2 presents the coefficients on the internet access measures in equation (1) across outcomes enumerated across rows. Overall job churn reduces (rows 1-2) with a reduction in new hires (row 1) in a magnitude relatively similar to the percentage reduction in job separation (row 2), yielding a statistically insignificant net change in employment (row 3). There is a reduction in the average monthly wage (row 4) and a similar reduction in measures of wage dispersion (rows 5-7); if changes in wage dispersions were effected through the employment margin, we might expect to see differential employment effects by relative skill levels whereby wage decreases were effected through a larger relative reduction in higher-skill, higher-wage employment. (We test this hypothesis below, and find that this was not the case.). In terms of total net economy-wide employment effects, on average across municipalities, there is no statistically significant change in employment attributable to internet access, although there is a 5.0% cumulative reduction in the average monthly wage that would result from a 100% change in a municipality’s internet access (given by $e^{(-0.024+-0.027)}-1$). The one-year-lagged effects of increases in internet access are typically larger than the

contemporaneous effects. This is the case for both labor market churn (via hiring and firing) and measures of wage dispersion.

Table 2: Contemporaneous and lagged effects of internet access on municipality-level worker outcomes
Municipality-year variation

Row	Outcome	lag Internet		N	Adj. R^2
		Internet	Coef. Coef.		
(1)	Total new hires	-0.024*	-0.102***	74170	0.921
(2)	Total separations	-0.036***	-0.087***	74170	0.923
(3)	Employment	-0.008	-0.005	74170	0.955
(4)	Average monthly wage	-0.024***	-0.027***	74170	0.802
(5)	SD (monthly wage)	-0.018**	-0.059***	74144	0.589
(6)	90-10 difference in ln(wage)	-0.001	-0.055***	74170	0.417
(7)	75-25 difference in ln(wage)	-0.005	-0.033***	74170	0.509

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

Employment and wages by 2-digit industry

Table 3 presents the coefficient estimates from this specification by industry. Among the five largest sectors by employment share, four have as-strong-or-stronger effects one year after a change in internet access; the only outlier is public administration, which does not sell in markets so its mission and activity levels are not likely to expand in response to lower marginal costs, and is more prone to have workers substituted for by ICT investments in the short run.

Table 3: Contemporaneous and lagged effects of internet access on municipality-level worker outcomes by sector

Municipality-year variation

Outcome/sector	Internet Coef.	lag Internet Coef.	N	Adj. R²
Employment - all sectors	-0.008	-0.005	74170	0.955
Employment - Wholesale & Retail	-0.038***	-0.079***	68288	0.972
Employment - Electric, gas, & water	-0.025**	-0.020*	68288	0.871
Employment - Manufacturing	0.024	0.025*	68288	0.944
Employment - Public Administration	-0.044***	-0.017	68288	0.766
Employment - Real Estate	0.018	0.046***	68288	0.914
Employment - Construction	0.008	0.004	68288	0.819
Employment - Agriculture	0.020*	-0.009	68288	0.942
Employment - Transport & Storage	0.066***	0.060***	68288	0.938
Employment - Other Soc. Svcs.	-0.005	0.007	68288	0.933
Employment - Health and Social Svcs.	0.030**	-0.015	68288	0.941
Employment - Hospitality	0.031***	0.017	68288	0.951
Employment - Education	0.007	0.019*	68288	0.937
Employment - Finance and Insurance	0.088***	0.043***	68288	0.953
Employment - Mining	0.019	0.019	68288	0.851
Employment - Fishing	-0.048***	0.054***	68288	0.732

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * p<.1, ** p<.05, *** p<.01.

Wage effects by industry group, presented in Table 4, are less stark. We find positive and statistically significant coefficients in agriculture, hospitality, real estate, and education sectors, with negative wage effects in utilities, transport & storage, and public administration.

Table 4: Contemporaneous and lagged effects of internet access on municipality-level worker outcomes by sector

Municipality-year variation

Outcome/sector	Internet Coef.	lag Internet Coef.	N	Adj. R²
ln(wage) - All	-0.024***	-0.027***	74170	0.802
ln(wage) - Wholesale & Retail	-0.002	-0.004	67070	0.717
ln(wage) - Electric, gas, & water	-0.024***	-0.045***	32793	0.752
ln(wage) - Manufacturing	0.002	0.008	58354	0.797
ln(wage) - Public Administration	-0.036***	-0.040***	67663	0.835
ln(wage) - Real Estate	0.020**	0.010	50093	0.593
ln(wage) - Construction	-0.006	0.004	46894	0.440
ln(wage) - Agriculture	0.002	0.006	61649	0.756
ln(wage) - Transport & Storage	-0.012**	-0.007	65279	0.575
ln(wage) - Other Soc. Svcs.	-0.004	0.008	58806	0.653
ln(wage) - Health and Social Svcs.	0.005	0.001	42532	0.705
ln(wage) - Hospitality	0.013**	0.013**	47423	0.597
ln(wage) - Education	-0.001	0.003	35929	0.769
ln(wage) - Finance and Insurance	0.002	-0.001	50176	0.646
ln(wage) - Mining	-0.011	0.008	25084	0.738
ln(wage) - Fishing	-0.004	-0.010	11542	0.584

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * p<.1, ** p<.05, *** p<.01.

Employment and wages by skill

We segment employment into terciles of relative skill level based on variation in mean wages across 300 3-digit occupations. We then estimate the employment and wage outcomes in Table 2 separately by skill groupings to assess whether overall effects can be attributable to differential labor market responses across skill levels. Table 5 presents these results, with some stark patterns: increased internet access reduced job churn and overall employment in both low- and high-skill occupations. Employment falls economy-wide for the lowest-skill tercile. Average wages decreased among the higher-skill occupations in response to internet access, and average wage inequality grew among the lowest skill tercile occupations but declined in the highest skill occupations.

Table 5: Effects of internet access on municipality-level worker outcomes, by skill level
Occupational skill tercile: First Second Third

Row	Outcome	Internet Coef.	lag Internet Coef.	Internet Coef.	lag Internet Coef.	Internet Coef.	lag Internet Coef.
(1)	Total new hires	0.002	-0.089***	0.014	-0.011	-0.065***	-0.111***
(2)	Total separations	0.001	-0.076***	-0.001	0.007	-0.047**	-0.058***
(3)	Employment	-0.019**	-0.073***	0.014	0.012	-0.024**	0.006
(4)	Average monthly wage	-0.001	0.000	-0.001	-0.002	-0.025***	-0.038***
(5)	SD (monthly wage)	-0.017	-0.051***	0.002	-0.041**	-0.013	-0.057***
(6)	90-10 difference in ln(wage)	0.018**	0.008	0.027*	-0.017	-0.020*	-0.078***
(7)	75-25 difference in ln(wage)	0.007*	0.003	0.006	-0.010	-0.007	-0.048***

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * p<.1, ** p<.05, *** p<.01.

We then estimate similar employment and wage coefficients by sector and skill level, shown in Table 6. (Note that not all sectors employ workers in each tercile, which leads to only some sector-skill cells being estimated.) The reduction in employment in wholesale and retail trade occurs largely among low-skill occupations, whereas the opposite is true among public administration (which is comprised of only high-skill occupations). The manufacturing sector sees gains in middle and higher skill occupations: on average across municipalities, the two-year cumulative effect of an increase in internet access (from 0 to 100%) on employment is 8.8% and 13.5% for medium- and high-skill occupations in manufacturing industries, respectively.

Table 6: Contemporaneous and lagged effects of internet access on municipality-level employment by sector and occupational skill level

Occupational skill tercile:	Municipality-year variation					
	First		Second		Third	
Outcome/sector	Internet Coef.	lag Internet Coef.	Internet Coef.	lag Internet Coef.	Internet Coef.	lag Internet Coef.
Employment - Wholesale & Retail	-0.037***	-0.073***	-0.007	-0.022*		
Employment - Electric, gas, & water					-0.026**	-0.020*
Employment - Manufacturing	0.015	-0.003	0.036**	0.049***	0.038**	0.089***
Employment - Public Administration					-0.041***	-0.019
Employment - Real Estate			0.031	0.041**	-0.052***	-0.038***
Employment - Construction			0.002	-0.008		
Employment - Agriculture	0.021	-0.007				
Employment - Transport & Storage			-0.004	-0.001	0.073***	0.065***
Employment - Other Soc. Svcs.	-0.008	-0.025**	0.002	0.011		
Employment - Health and Social Svcs.			0.031*	-0.026*		
Employment - Hospitality	0.026*	0.009				
Employment - Education					0.007	0.019
Employment - Finance and Insurance					0.088***	0.044***
Employment - Mining	0.014	0.018			-0.005	-0.012
Employment - Fishing	-0.046***	0.054***				

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * p<.1, ** p<.05, *** p<.01.

Estimates of effects on wages by sector and tercile are presented in Table 7. Positive wage effects are generally found among the lower and middle skill terciles, while internet access appears to have a negative effect on wages in the highest skill occupations. Manufacturing and real estate are an exception, exhibiting wage increases in both the middle and high skill occupations. Both the public sector and utilities show wage decreases among its highly skilled occupations. On average across municipalities, the two-year cumulative effect of an increase in internet access (from 0 to 100%) on monthly wages is 4.8% and 4.1% for medium and high-skill tercile occupations across manufacturing industries, respectively.

Table 7: Contemporaneous and lagged effects of internet access on municipality-level wages by sector and occupational skill level

Occupational skill tercile:	Municipality-year variation					
	First		Second		Third	
	Internet	lag Internet	Internet	lag Internet	Internet	lag Internet
Outcome/sector	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
ln(wage) - Wholesale & Retail	-0.006	-0.002	0.004	-0.002		
ln(wage) - Electric, gas, & water					-0.024**	-0.045***
ln(wage) - Manufacturing	0.004	0.003	0.029***	0.018*	0.001	0.041***
ln(wage) - Public Administration					-0.035***	-0.040***
ln(wage) - Real Estate			0.019**	0.016*	0.038*	0.024
ln(wage) - Construction			-0.006	0.006		
ln(wage) - Agriculture	0.002	0.005				
ln(wage) - Transport & Storage			-0.019	0.011	-0.018***	-0.008
ln(wage) - Other Soc. Svcs.	0.027**	-0.002	-0.001	0.004		
ln(wage) - Health and Social Svcs.			0.005	0.001		
ln(wage) - Hospitality	0.013**	0.013**				
ln(wage) - Education					-0.002	0.003
ln(wage) - Finance and Insurance					0.002	-0.001
ln(wage) - Mining	-0.010	0.016			0.012	-0.049
ln(wage) - Fishing	-0.004	-0.010				

Note: Estimates based on RAIS employee-employer records aggregated by municipality and year merged to internet access data from the School Census. Outcome measures listed in rows are in natural log. Interpretation of coefficients relate an increase in internet access from 0% to 100% in the municipality to the percent change in the outcome measure. Rows indicate outcome used in a common specification including unreported vectors of municipality and year fixed effects and a constant term. Standard errors clustered by municipality in parentheses. * p<.1, ** p<.05, *** p<.01.

IV. Conclusions and policy considerations

Based on a novel data set that we construct on staggered internet availability by municipality between 2000 and 2014, combined with Brazil's matched employer-employee data set (RAIS), we find that increased internet access had no statistically significant net economy-wide effect on aggregate employment and a negative effect on average wages, with a reduction in measures of wage dispersion. The absence of economy-wide significant net employment effects masks important shifts in employment from sectors with more limited expansion opportunities—wholesale and retail trade, public administration and (largely publicly-owned) utilities that comprise almost half of the formal workforce in 2010—to sectors with more output expansion possibilities. Employment effects are positive and most pronounced in transport and storage, finance and insurance, real estate and manufacturing industry groups. Importantly, internet adoption in manufacturing industries is moderately inclusive, with positive employment and wage effects across both high and medium-skill workers. On average across municipalities, the two-year cumulative effect of an increase in internet access (from 0 to 100%) is 8.8% and 13.5% on employment, and 4.8% and 4.1% on average monthly wages, for medium- and high-skill occupations in manufacturing industries, respectively.

Regarding the types of policies that could help offset the uneven sectoral negative employment impacts of internet rollout that we have found, and the negative effects on unskilled workers that Akerman et al. (2015) have found,⁴ there is an important policy thrust to emphasize in addition to the presence of job training and other input-support programs that should be responsive to the changing market needs of new and growing firms. As highlighted in Brambilla's (2017) useful conceptual framework, internet rollout and the attendant ICT adoption by firms can generate output-expansion effects that, if sufficiently large, will increase firm labor demand of both skilled and unskilled workers, more than offsetting the substitution effects from unskilled to skilled workers, and even the partial replacement of skilled workers by ICT investments to the extent that skilled workers and ICT are substitutes in specific industry groups. It is striking that the statistically significant employment effects by industry group in Brazil are consistently positive only for manufacturing, transport and storage, finance and insurance, and hospitality, which are industry groups that seem likely to be composed of firms that are able to take advantage of opportunities to sell more as their marginal costs decline, both in terms of more sales within Brazil outside of the municipality and more exports (either directly or indirectly). Public administration does not sell in any market so its mission and activity levels are not likely to be responsive to lower marginal costs, at least not in the short or even medium term. Thus, there it is no surprise that substitution effects predominate. As for wholesale and retail occupations, what those workers help to sell is not likely to have sales prices that are much diminished as the costs of retail and wholesale services decline. Thus, it is likely that the activity levels of these occupations that are demanded in the market are not elastic with respect to the costs of producing the services of retail and wholesale workers and the ICT they may utilize. So, output effects are likely small or non-existent, and substitution effects are expected to predominate, as confirmed by our analysis.

One important policy perspective that is beyond the scope of this paper is what becomes of the displaced workers in public administration and in the retail and wholesale services occupations. Do they move into jobs in sectors where they are more relatively productive? Do the sectors that can adopt ICT and elevate their outputs more effectively wind up employing those displaced, if not in the same year as the ICT

⁴ Akerman et al. (2015) exploit rich Norwegian data to answer similar questions to our study. In Norway, a public program with limited funding rolled out broadband access points, and provides plausibly exogenous variation in the availability and adoption of broadband internet in firms. Their results suggest that broadband internet improves (worsens) the labor outcomes and productivity of skilled (unskilled) workers. They explore several possible explanations for the skill complementarity of broadband internet. They find suggestive evidence that broadband adoption in firms complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks.

adoption then perhaps in the next year or thereafter? We hope to illuminate these questions in subsequent work.

Two dual categories of directions for policy to help all workers be included in the benefits from ICT adoption are highlighted by our work: policies to foster job mobility and policies to foster output expansion as productivity is raised. To the extent that policies can help support worker mobility and skill adaptability as well as make industry group output demands more elastic through reductions in transport, logistics and trade costs, so that output expansion is more responsive to firm efficiency improvements, then output expansion in response to internet rollout and associated ICT adoption can be that much more important, thereby expanding employment of all skills.

References

- Acemoglu, Daron and David Autor (2011), "Skills, Tasks and Technologies: Implications for Employment and Earnings," *Handbook of Labor Economics*, volume 4.
- Acemoglu, Daron and Pascual Restrepo (2016), "The race between machine and man: Implications of technology for growth, factor shares and employment," NBER Working Paper No. 222521, May.
- Aghion, Philippe and Peter Howitt (2009), *The Economics of Growth*, Cambridge, MA: MIT Press.
- Alesina, A., M. Battisti and J. Zeira (2015), "Technology and Labor Regulations: Theory and Evidence," NBER Working Paper no. 20841, Cambridge MA
- Akerman, Anders, Ingvil Gaarder and Magne Mogstad (2015), "The Skill Complementarity of Broadband Internet," NBER Working Paper No. 20826, January.
- Asker, John, Allan Collard-Wexler, and Jan De Loecker (2014) "Dynamic Inputs and Resource (Mis)Allocation," *Journal of Political Economy* Vol. 122, No. 5, pages 1013-1063.
- Autor, David (2015), "Why are there still so many jobs? The history and future of workplace automation," *Journal of Economic Perspectives*, 29: 3 (Summer), 3-30.
- Autor, David and David Dorn (2013). "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market," *American Economic Review* 103(5): 1553–1597.
- Bartelsman, Eric, John Haltiwanger, and Stefano Scarpetta (2013). "Cross-Country Differences in Productivity: The Role of Allocation and Selection," *American Economic Review*, Vol. 103, No. 1 (February), pages 305-334.
- Brambilla, Irene (2017). "Digital Technology Adoption and Jobs: A Model of Firm Heterogeneity," Mimeo (January).
- Comin, Diego and M. Mestieri Ferrer (2013), "If Technology Has Arrived Everywhere, Why Has Income Diverged?" NBER Working Paper 19010, Cambridge, MA
- De La Torre, Augusto, Alain Ize, Guillermo Raul Beylis, and Daniel Lederman, 2015. *Jobs, wages, and the Latin American slowdown*. Washington, D.C. World Bank Group.
- De Loecker, Jan, and Frederic Warzynski (2012). "Markups and Firm-Level Export Status," *American Economic Review*, Vol. 102, No. 6 (October), pages 2437-2471.
- Dutz, Mark, Lucas Ferreira-Mation, Stephen O'Connell and Robert Willig (2015), "Technological change and labor market segmentation in the developing world: Evidence from Brazil", *Background Paper World Development Report 2016*.
- Dutz, Mark, Ioannis Kessides, Stephen O'Connell and Robert Willig (2012), "Competition and innovation-driven inclusive growth," Chapter 7 in *Promoting Inclusive Growth: Challenges and Policies*, Luiz de Mello and Mark Dutz (eds.), OECD, 2012; and Policy Research Working Paper 5852, The World Bank, October 2011.

Hollweg, C., D. Lederman and D. Mitra (2015), “Structural Reforms and Labour-market Outcomes: International Panel-data Evidence,” *The World Economy*.

Pagés, Carmen (2010), *The Age of Productivity: Transforming Economies from the Bottom Up*. Inter-American Development Bank, Washington, DC.

Song, Jae, David Price, Fatih Guvenen and Nicholas Bloom (2016), “Firming Up Inequality,” Mimeo, October.

World Bank (2016), *World Development Report 2016: Digital Dividends*, The World Bank, Washington, DC