The Impact of Digital Technology on Worker Tasks: Do Labor Policies Matter?

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May 15, 2023

4th Joint IMF-OECD-World Bank Conference on Structural Reforms

Motivation

- Technological progress promotes productivity and growth.
  - Few would argue against the positive impact the digital revolution of the last two decades has had on the economy—both globally and locally.
- At the same time, there is a concern that some tasks (namely, the more routine, codified tasks) are being replaced by technology, effectively displacing lower-skilled workers.
  - This routinization hypothesis has been confirmed for the developed world (Autor, Levy, & Murnane 2003; Goos, et al. 2009; Akerman, et al. 2015; Bockerman, et al. 2016).
- Labor market institutions ideally exist to protect workers from such shocks.
  - These social protections also have the unintended consequence of increasing the adjustment cost of labor for businesses (Almeida & Carneiro 2009; 2012).
- Policymakers must weigh the long-term broad economic benefits against the potential short-run costs to some groups.

What & How?

- **Question:** we analyze the impact of digital technology adoption on local demand for different skills in a middle-income country setting and assess the extent to which labor regulations constrain adjustment, differentially across tasks.
  - Tasks: the degree to which businesses use different abilities and activities (ONET)

- **Methodology:** we exploit subnational variation between 1999 and 2006 across Brazilian cities in access to digital technology and time-invariant industry-specific use of information technology to identify the effect of digital technology on the use of different competencies across occupations; we, then, further explore the role of subnational enforcement of labor regulations.
  - Municipality-time: subnational internet rollout driven by the privatization of the telecommunications industry (MUNIC)
  - Industry: use of information and communications technology (CPS)
  - Municipality-time: enforcement of labor regulations as captured by the incidence of labor inspections (MTE)

Main Findings

- **Main Finding #1:** Digital technology adoption increases relative use of non-routine activities and cognitive abilities among Brazilian businesses in high-tech industries relative to low-tech industries.
  - Among set of routine *activities*, there is a relative shift toward routine-cognitive;
  - Among set of cognitive *abilities*, there is a relative shift towards interactive and communication-based skills.

- **Main Finding #2:** In contrast to the best policy intentions of supporting the most vulnerable workers, *de facto* labor market regulations differentially benefit the most skilled workers.
  - Regulations increase the cost of adjustment and stifle turnover; the cost of adjustment is higher for high-skilled (high wage) workers.

- **Policy Implications:** prominent public policy debate relates to economic growth versus job security.
  - What are the job requirements in a technologically-advancing world, and how can policy help to promote them?

Contribution

- The impact of technology on the labor market is a topic of constant discussion.
  - Autor, Levy, & Murnane (2003), Goos, et al. (2009), Acemoglu & Autor (2011), Akerman, et al. (2015), and Bockerman, et al. (2016) confirm “routine-biased technical change” for the developed world.
  - Messina, et al. (2015), Maloney & Molina (2016) offer some descriptive evidence on job polarization for Latin America; Riva (2015), Hjort & Poulson (2019) and Almeida, et al. (2018) offer evidence linking technological adoption and the demand for skills for Brazil, African countries, and Chile, respectively.

- A large and growing literature on the impact of labor regulations on the labor outcomes in developing settings (e.g., Heckman & Pages 2004).
  - Bertola, et al. (2000) suggest that enforcement is as (if not more) important than regulations.
  - Almeida & Carneiro (2009, 2012), Almeida & Poole (2017), and Almeida, Paz, & Poole (2022) show evidence consistent with the idea that enforcement of labor regulations in Brazil constrains firm size, limits firm productivity, and lowers job quality.

- *We are not aware of any paper allowing for technology shocks to impact industries differently depending on their exposure to labor market regulations.*

Conceptual Framework: I

- **Goal # 1:** Assess the extent to which the adoption of digital technologies affects the relative demand for skills (abilities/activities).

- **Hypothesis:** Theory offers an ambiguous prediction.
  - **Relative increase in routine skills:** On the one hand, with the expansion of the internet, digital technologies may replace more sophisticated, cognitively-oriented tasks, as computing and communications technology *substitute* for skilled workers.
  - **Relative increase in non-routine skills:** On the other hand, perhaps higher-skilled workers *complement* the new computer-based tasks associated with digital technologies and computers substitute for more routine tasks.

- Given the evidence in the literature, we hypothesize that, while both effects may play a role, digital technologies shift local labor demand away from routine and manual tasks.

Conceptual Framework: II

- **Goal #2:** Exploit the role of social protections in influencing the impact of digital technology on the relative demand for skills.

- **Hypothesis:** Theory offers an ambiguous prediction.
  - **Relative increase in routine skills:** Regulations are designed to protect the most vulnerable workers from adverse economic shocks.
  - **Relative increase in non-routine skills:** Labor adjustment cost is proportional to the cost of labor; regulations restrict labor adjustment of skilled more than unskilled workers.

- In Brazil, dismissal costs are directly related to the wage level. For this reason, we hypothesize that, while both effects may play a role, *de facto* regulations differentially benefit skilled workforce.
  - Montenegro & Pages (2004) provide support for the idea that labor market regulations reduce employment rates of the unskilled at the benefit of the skilled.

Data Sources: RAIS

- **Worker-Establishment Data:** *Relação Anual de Informações Sociais* (RAIS)
  - linked employer-employee data collected by Brazilian Ministry of Labor (MTE)
  - administrative records on all formally-employed workers in legally-registered establishments
  - unique worker identification code, tax identifier of the worker's establishment, industrial classification of the worker's establishment (4-digit CNAE), municipality of the worker's establishment, detailed human capital measures (occupation at 5-digit CBO).
- We exclude data pertaining to the public sector and to the agricultural sector, following the MTE.
- As is common in the literature, we only consider establishments with 5 or more employees.
- In 1999, our data includes over 16 million workers across ~300,000 establishments. Workers were employed in 2,312 different occupations, and establishments produced in 574 industries and were located in 3,479 Brazilian cities.

Data Sources: O*NET

- **Task Content Data:** *Occupational Information Network*
  - The U.S. Department of Labor surveys workers on the skills required in their occupations
  - These occupation-specific attributes are maintained in the O*NET database across approximately 800 Standard Occupational Classification occupations for the year 2000.
  - O*NET offers "importance scores" for 52 abilities and 41 activities (1=Not Important; 5=Important)
  - Our main assumption is that the skill-intensity of an occupation in U.S. is similar in Brazil.
  - We rely on publicly-available concordances to match CBO-ISCO-SOC.
- We normalize (between 0 and 1) O*NET's importance scores using the maximum value for that score across all occupations.

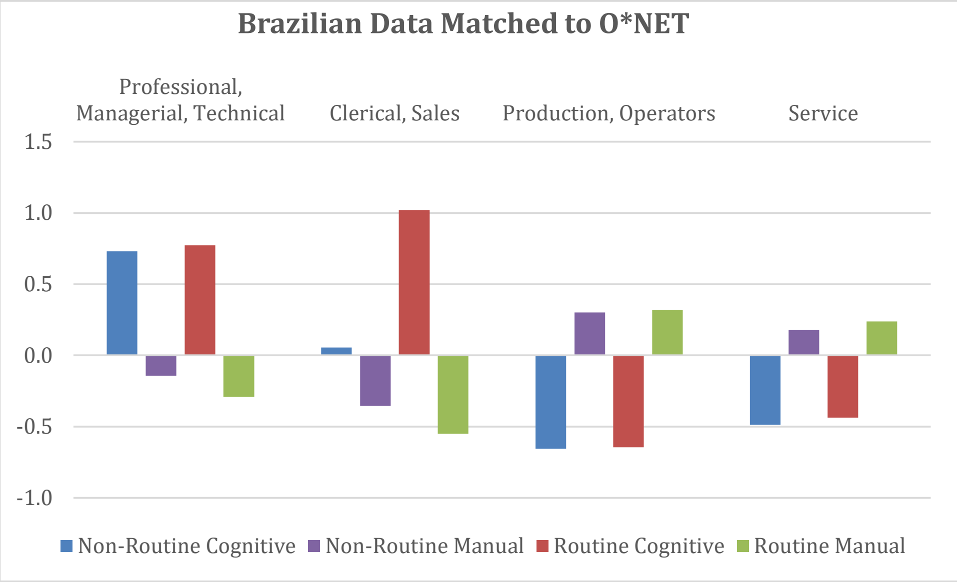
$$S'_{c,a} = \frac{S_{c,a}}{\text{argmax}\,\{S_{1,a},\ldots,S_{C,a}\}}$$

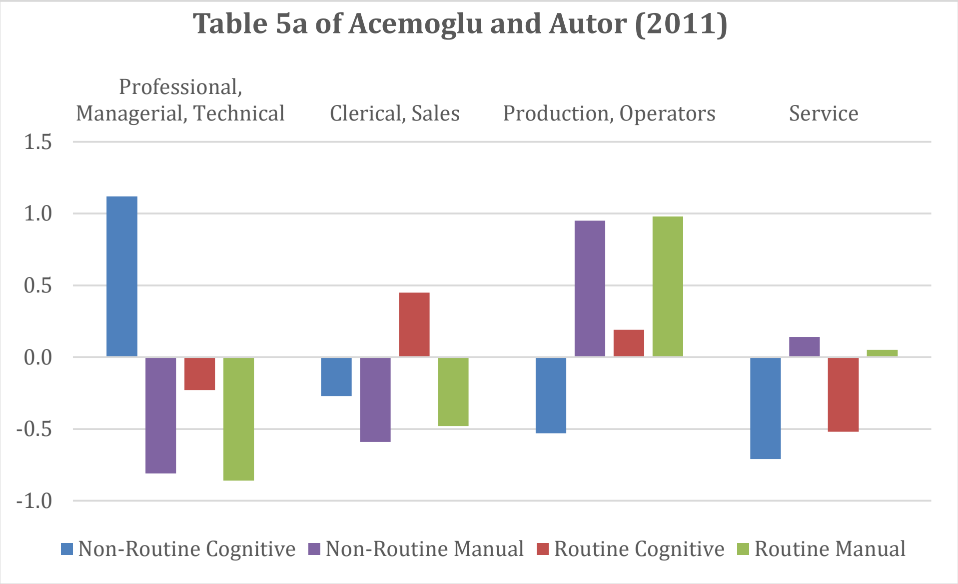
Data Sources: O*NET

- Our interest is in broader skill groupings, so we classify occupational *abilities* into cognitive and manual abilities and occupational *activities* into routine and non-routine activities.
  - Other papers relying on O*NET often hand-pick attributes

- **City-Industry Tasks:** aggregate over all workers within the city and industry to characterize local time-varying average task use
  - The time-variation in our main dependent variable comes solely from labor force adjustments overtime.
  - As is common in research on skills, we focus on the relative shift of tasks across skill groups.

Data Sources: O*NET





Data Sources: MUNIC

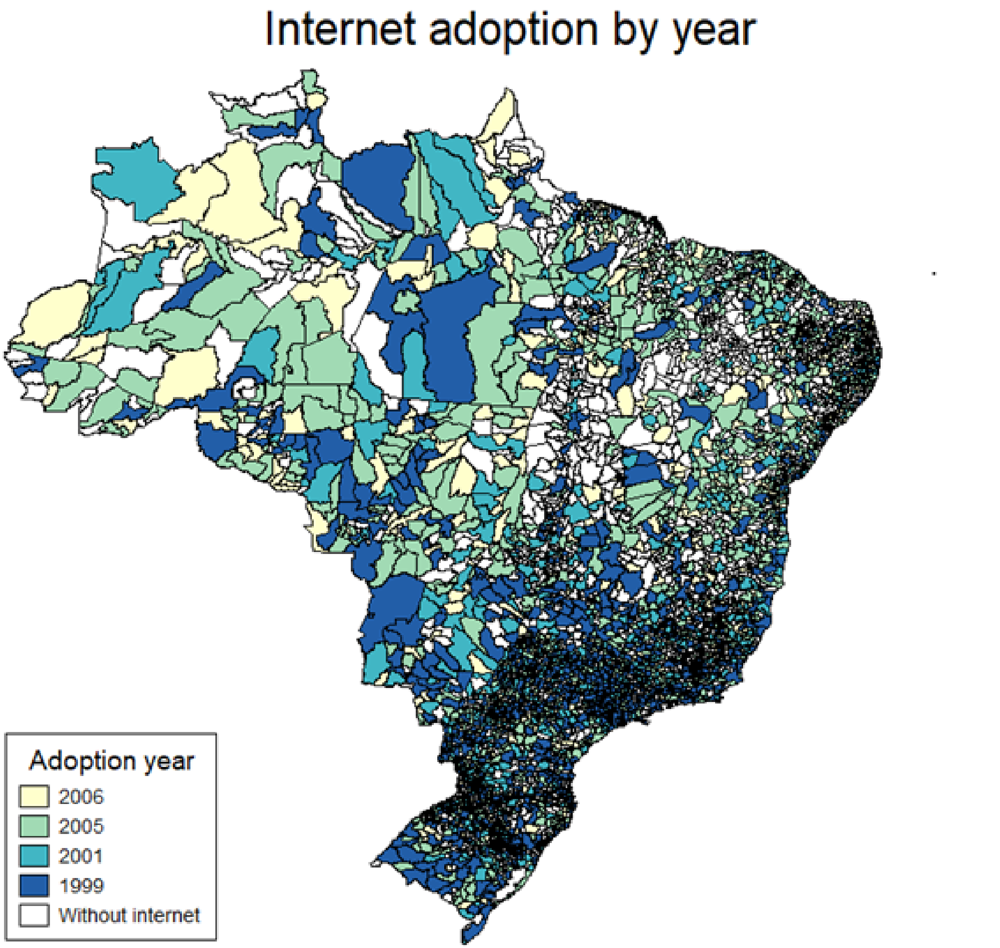
- **Internet Data:** *Pesquisa de Informações Básicas Municipais* (MUNIC)
  - Brazilian Census Bureau (IBGE) surveys all cities on structure and function of municipal institutions.
  - In some years, they ask about "cultural" activities—among the questions are whether the city has a company that provides internet services.
  - This variable serves as our main supply-side access to technology.

Table 3.3: Internet Service Provision, 1999-2006

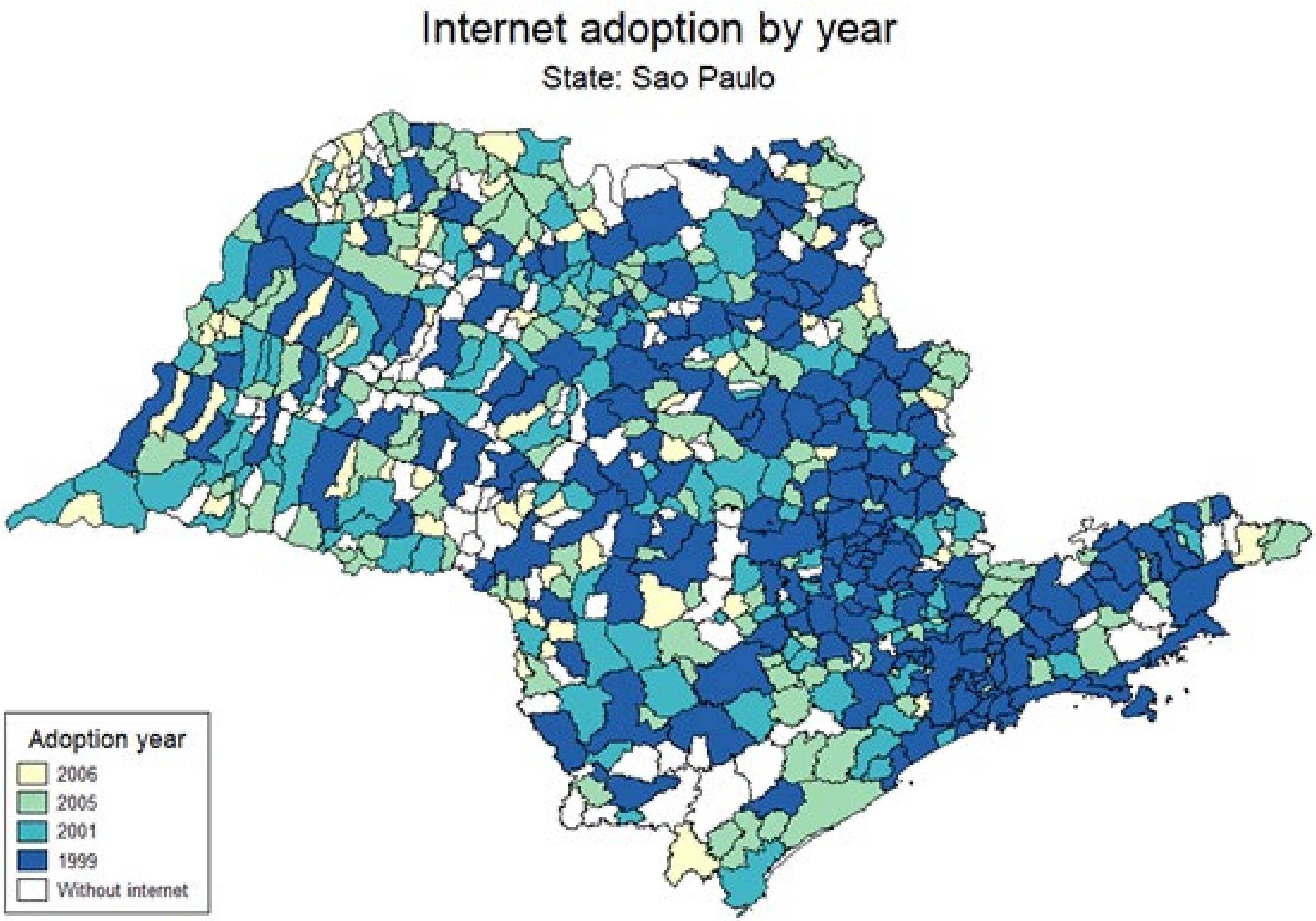
	Share of Cities with Internet Services (1)	Share of Population with Internet Services (2)	Number of Cities with New Internet Services (3)	Share of Cities with New Internet Services (4)
1999	0.15	0.61	-	-
2001	0.26	0.71	599	0.11
2005	0.51	0.84	1390	0.25
2006	0.61	0.88	555	0.10

Source: IBGE.

Data Sources: MUNIC



Data Sources: MUNIC



Data Sources: CPS

- **Industry Technology-Intensity Data:** *Current Population Survey* (CPS)
  - October 2003 supplement asks U.S. households whether they use a computer at work
  - Time-invariant share of workers by industry using information and communications technology
  - Rely on publicly-available concordances across U.S. and Brazilian classifications to measure the technology-use across detailed Brazilian industries
  - Findings are sensible:
    - Most tech-intensive industry: “Electronic computer manufacturing” reports over 85 percent of workers use a computer at work
    - Least tech-intensive industries: Less than 30 percent of workers use a computer at work in “Farm machinery and equipment manufacturing”

- This variable serves as our main demand-side use of technology.
  - It is a proxy for how intense would be the use of technology across industries in Brazil if such technology was as widespread as in the United States

Labor Policy Background

- Brazil has a very restrictive labor market regulatory framework: 1988 Constitution is very favorable to workers; it increased the cost of employing workers (relative to capital) for businesses.
  - Almeida & Carneiro (2009, 2012); Almeida & Poole (2017); Almeida, Paz, & Poole (2022).
- There was an increase in the cost of dismissals
  - Employer penalty for dismissing workers without cause increased from 10% to 40%
  - Employers must give advanced notice; 25% of remaining time allocated to job search
- Labor Ministry is tasked with ensuring compliance with these regulations.
  - Send inspectors to ensure formal work registration, health and safety conditions, adherence to minimum wage laws, and maximum working lengths by employers.
  - Inspections are triggered by a random audit or anonymous report by workers, union representatives, public prosecutor's office, police.
  - Plants are fined if they are found to have violated regulations.
- Given the geographic size, there is significant heterogeneity both within the country and over time in how binding is the law.
  - There is a gap between laws (*de jure* regulations) and their effective implementation (*de facto* regulations).

Data Sources: MTE

- **Enforcement Data:** *Ministry of Labor Inspections*
  - Every single labor inspection must be registered in an information system hosted by the Brazilian Labor Ministry (MTE)
  - We use administrative data from MTE by city, broad sector, and year on the number of inspector visits

- We proxy the degree of regulatory enforcement, by the *intensity* of labor inspections at the city-sector level.
  - We scale the number of labor inspections by the number of establishments in the city-sector (in a pre-reform period, 1995).
  - The scaled measure helps to control for important size differences across cities
  - Also, by scaling by a time-invariant measure of size, we know that changes in the intensity are due to changes in inspections and not changes in the size of the city.
  - Measure reflects the direct effect of inspections as well as the perceived threat of inspections.

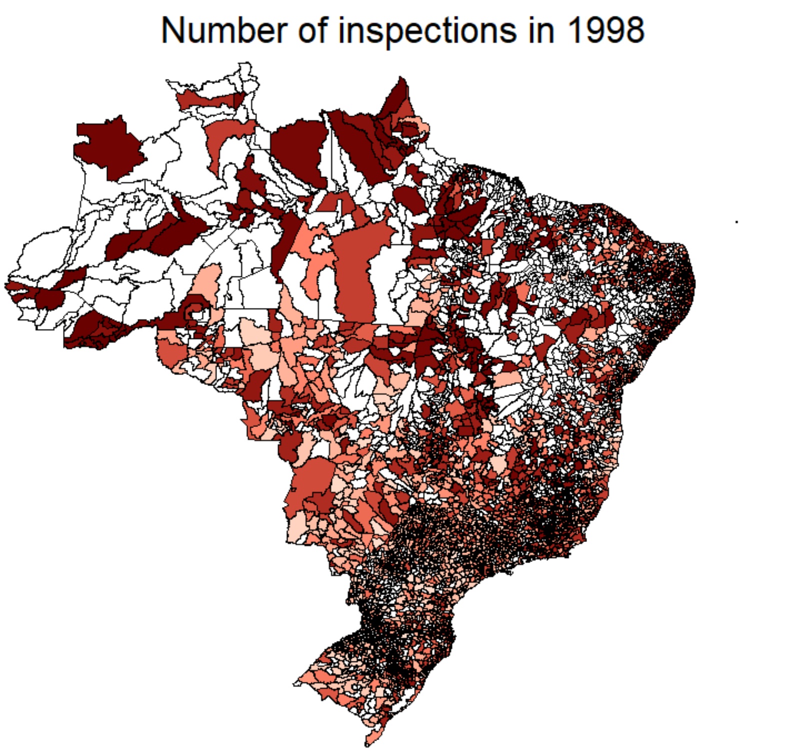
Data Sources: MTE

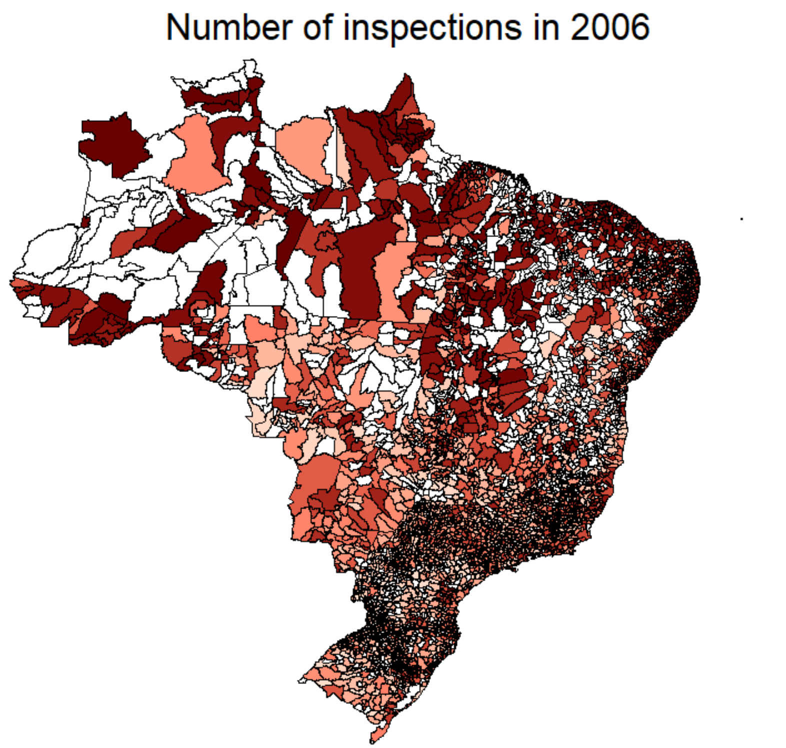
Table 3.5: Enforcement of Labor Regulations, 1998-2006

	Share of Cities Inspected	Average Number of Inspections	Average Inspections Per 100 Registered Establishments in 1995	Standard Deviation of Inspections per 100 Registered Establishments in 1995
	(1)	(2)	(3)	(4)
1998	0.55	68.5	12	32
2000	0.62	81.5	18	44
2004	0.62	64.2	20	113
2006	0.67	72.5	23	83

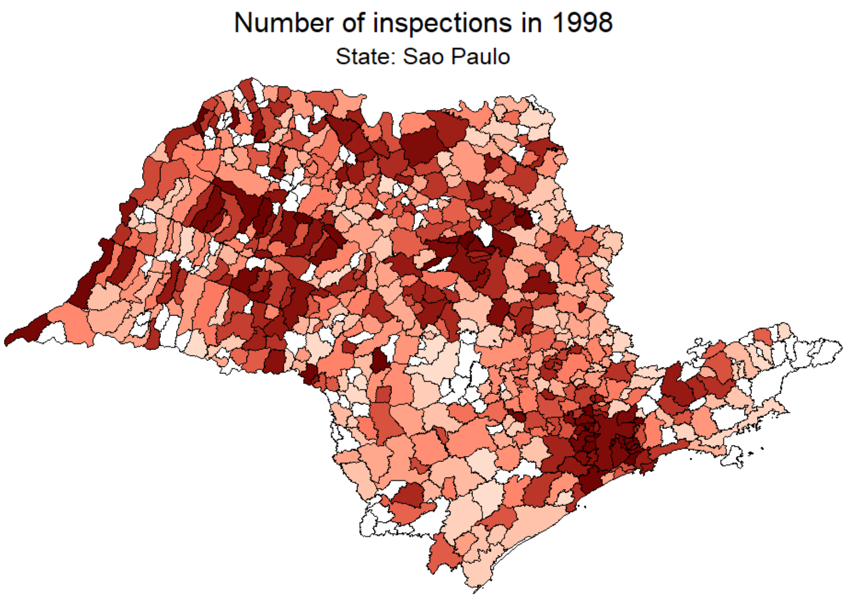
Sources: Ministry of Labor administrative data on inspections; RAIS.

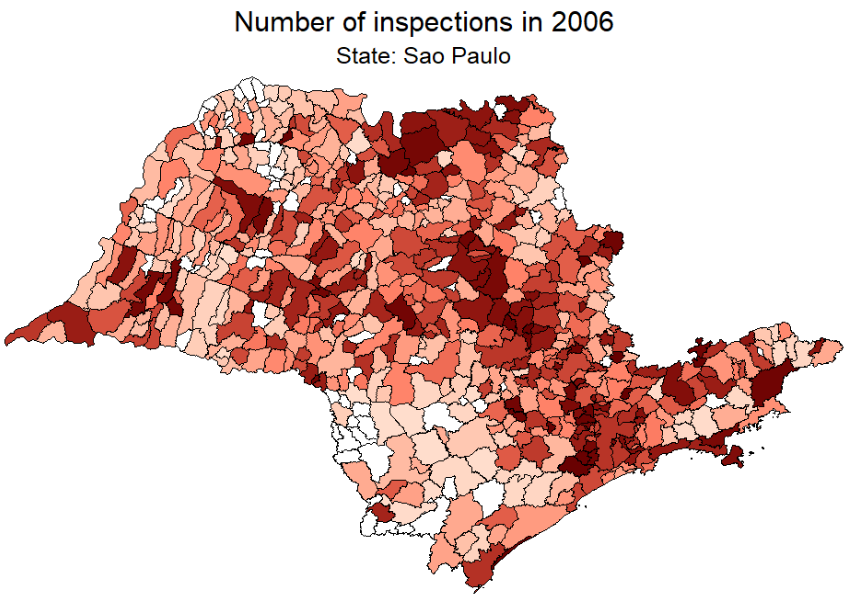
Data Sources: MTE





Data Sources: MTE





Empirical Methodology: I

- **Goal**: assess the extent to which the adoption of digital technology affects the relative demand for skills

$$y_{mkt} = \beta_1(INTER_{mt} * USE\_TEC_k) + \beta_2 INTER_{mt} + \varphi_{mk} + \delta_{Kst} + \varepsilon_{mkt}$$

  - $INTER_{mt}$: expansion of internet services across cities over time (supply-side)
  - USE_TEC_k: industries vary in the degree of reliance on digital technology (demand-side)
  - Industries which intensively-use technology located in areas with early provision of services are likely adopters of digital technology.
- The effect of internet services is identified using across-municipality differences in internet services provision over time for industries that differentially use information technology (triple differences framework).
- β_1 reports the impact of digital technology in high-tech industries relative to low-tech industries
  - To be clear, such a relative effect does not rely on an exogenous internet rollout across municipalities.

Digital Technology & Abilities

Table 5.1: The Effect of Digital Technology on Tasks

Dep. Variable:	Panel A: Log (Cognitive/Manual Tasks)$_{mkt}$		
	Basic set of controls	Intermediate set of controls	Complete set of controls
	(1)	(2)	(3)
$INTER_{mt}$*USE_TEC_k	0.014***	0.016***	0.013***
	(0.004)	(0.004)	(0.004)
$INTER_{mt}$	-0.009***	-0.010***	-0.008***
	(0.002)	(0.002)	(0.002)
Sector-State-Year Dummies	YES	YES	YES
City-Industry Fixed Effects	YES	YES	YES
City-Industry-Year Controls	NO	YES	YES
Technology Controls	NO	NO	YES
Observations	383,725	383,725	383,725

Sources: RAIS; O*NET; IBGE; CPS.

Digital Technology & Activities

Table 5.1: The Effect of Digital Technology on Tasks

Dep. Variable:	Panel B: Log (Non-Routine/Routine Tasks)$_{mkt}$		
	Basic set of controls	Intermediate set of controls	Complete set of controls
	(4)	(5)	(6)
$INTER_{mt}$*USE_TEC_{k}	0.038***	0.039***	0.035***
	(0.004)	(0.004)	(0.004)
$INTER_{mt}$	-0.018***	-0.018***	-0.016***
	(0.002)	(0.002)	(0.002)
Sector-State-Year Dummies	YES	YES	YES
City-Industry Fixed Effects	YES	YES	YES
City-Industry-Year Controls	NO	YES	YES
Technology Controls	NO	NO	YES
Observations	383,725	383,725	383,725

Sources: RAIS; O*NET; IBGE; CPS.

Empirical Methodology: II

- The degree to which employers adjust skills in response to a digital technology shock depends on the stringency of the labor market regulatory enforcement they face.

$$y_{mkt} = \gamma_1(ENF_{mKt-1} * INTER_{mt} * USE\_TEC_k) + \gamma_2(ENF_{mKt-1} * INTER_{mt}) + \gamma_3(ENF_{mKt-1} * USE\_TEC_k) + \gamma_4 ENF_{mKt-1} + \beta_1(INTER_{mt} * USE\_TEC_k) + \beta_2 INTER_{mt} + \varphi_{mk} + \delta_{Kst} + \varepsilon_{kmt}$$

- γ_1 captures the distinct effect of internet adoption according to the level of regulatory enforcement, or the heterogeneity in β_1 across regulatory enforcement regimes
- We rely on differential effects of quasi-exogenous technology shocks for industries located in diverse policy environments—a quadruple-interaction effect.

Table 5.4: The Effect of Digital Technology on Tasks, by Labor Market Enforcement

Dep. Variable:	Panel A: Log (Cognitive/Manual Tasks)$_{mkt}$		
	Basic set of controls	Intermediate set of controls	Complete set of controls
	(1)	(2)	(3)
$INTER_{mt}$*USE_TEC_k	0.023***	0.026***	0.024***
	(0.006)	(0.006)	(0.006)
$INTER_{mt}$	-0.014***	-0.015***	-0.014***
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}*$INTER_{mt}$*USE_TEC_k	0.006*	0.007**	0.008**
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}*$INTER_{mt}$	-0.003**	-0.004**	-0.005***
	(0.002)	(0.002)	(0.002)
ENF_{mKt-1}*USE_TEC_k	-0.006**	-0.007**	-0.008**
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}	0.003*	0.003**	0.003*
	(0.002)	(0.002)	(0.002)
Sector-State-Year Dummies	YES	YES	YES
City-Industry Fixed Effects	YES	YES	YES
City-Industry-Year Controls	NO	YES	YES
Technology Controls with Enforcement Interactions	NO	NO	YES
Differential Impact of Internet in Tech-Intensive Industries			
Located in Cities at the 90th Percentile of Inspections	0.022***	0.025***	0.022***
F-statistic	17.2	22.5	17.2
Located in Cities at the 10th Percentile of Inspections	0.005	0.005	0.001
F-statistic	0.7	0.7	0.0
Difference in Differential Impact of Internet in Tech-Intensive Industries			
90th Percentile - 10th Percentile of Inspections	0.016*	0.019**	0.022**
F-statistic	3.5	4.9	5.6
Observations	383,725	383,725	383,725

Sources: RAIS; O*NET; Ministry of Labor; IBGE; CPS.

Table 5.4: The Effect of Digital Technology on Tasks, by Labor Market Enforcement

Dep. Variable:	Panel B: Log (Non-Routine/Routine Tasks)$_{mkt}$		
	Basic set of controls	Intermediate set of controls	Complete set of controls
	(4)	(5)	(6)
$INTER_{mt}$*USE_TEC_k	0.062***	0.064***	0.056***
	(0.006)	(0.006)	(0.006)
$INTER_{mt}$	-0.028***	-0.029***	-0.026***
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}*$INTER_{mt}$*USE_TEC_k	0.018***	0.018***	0.016***
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}*$INTER_{mt}$	-0.007***	-0.008***	-0.007***
	(0.002)	(0.002)	(0.002)
ENF_{mKt-1}*USE_TEC_k	-0.013***	-0.014***	-0.019***
	(0.003)	(0.003)	(0.003)
ENF_{mKt-1}	0.005***	0.006***	0.007***
	(0.002)	(0.002)	(0.002)
Sector-State-Year Dummies	YES	YES	YES
City-Industry Fixed Effects	YES	YES	YES
City-Industry-Year Controls	NO	YES	YES
Technology Controls with Enforcement Interactions	NO	NO	YES
Differential Impact of Internet in Tech-Intensive Industries			
Located in Cities at the 90th Percentile of Inspections	0.059***	0.061***	0.054***
F-statistic	121.5	128.5	96.4
Located in Cities at the 10th Percentile of Inspections	0.010	0.010	0.009
F-statistic	2.3	2.2	2.0
Difference in Differential Impact of Internet in Tech-Intensive Industries			
90th Percentile - 10th Percentile of Inspections	0.049***	0.051***	0.044***
F-statistic	31.6	34.1	23.6
Observations	383,725	383,725	383,725

Sources: RAIS; O*NET; Ministry of Labor; IBGE; CPS.

Robustness Checks

- 1/ Additional time-varying city and industry controls, including those for city-specific technology development
- 2/ Key to our identification strategy:
  - Changes in the city-industry outcome variables in high-tech relative to low-tech industries would have been the same had the internet never arrived.
  - We consider pre-internet trends in skill indices across municipalities and industries.
- 3/ Current identification relies on timing of internet and whether internet exists in the city
  - a/ We restrict the sample to only those cities who have access to internet by 2006.
  - b/ We include the full set of city-year fixed effects
- 4/ Only formal cities
- 5/ Time-invariant labor market enforcement
- 6/ Increases versus decreases in enforcement

Conclusions

- Consistent with other evidence from the developed and developing world, in Brazil, increased access and use of new digital technology shifts labor demand toward non-routine and cognitively-oriented tasks.
  - Within cognitive abilities, interpersonal and communication skills are at a premium.

- The shift toward non-routine and cognitive tasks is stronger in cities with stricter enforcement of regulations.
  - In contrast with labor policy intentions, regulations seem to favor skilled workers.

Policy Implications

- For education and training policies, there are direct implications to support the development of cognitive and communication skills.

- In terms of job security, and the ability to offer lower-skilled workers protections from technology-related job displacement, enhanced regulatory enforcement may be welcome.

- By contrast, to the extent that employers may not fully benefit from the productivity gains associated with technological change, due to restricted labor adjustment, policymakers should consider alternative forms of social protections.
  - Current discussion surrounding more flexibility in times of crisis

Thank you!

Data Sources: O*NET

Table 3.1: O*NET Abilities Classification

Manual Abilities		Cognitive Abilities	
Precision	Other	Analytical	Communication
Arm-Hand Steadiness	Reaction Time	Fluency of Ideas	Oral Comprehension
Manual Dexterity	Wrist-Finger Speed	Originality	Written Comprehension
Finger Dexterity	Speed of Limb Movement	Problem Sensitivity	Oral Expression
Control Precision	Static Strength	Deductive Reasoning	Written Expression
Multilimb Coordination	Explosive Strength	Inductive Reasoning	Speech Recognition
Response Orientation	Dynamic Strength	Information Ordering	Speech Clarity
Rate Control	Trunk Strength	Category Flexibility	
	Stamina	Mathematical Reasoning	
	Extent Flexibility	Number Facility	
	Dynamic Flexibility	Memorization	
	Gross Body Coordination	Speed of Closure	
	Gross Body Equilibrium	Flexibility of Closure	
	Near Vision	Perceptual Speed	
	Far Vision	Spatial Orientation	
	Visual Color Discrimination	Visualization	
	Night Vision	Selective Attention	
	Peripheral Vision	Time Sharing	
	Depth Perception		
	Glare Sensitivity		
	Hearing Sensitivity		
	Auditory Attention		
	Sound Localization		

Source: O*NET.

Data Sources: O*NET

Table 3.2: O*NET Activities Classification

Routine Activities		Non-Routine Activities	
Manual	Cognitive	Manual	Cognitive
Performing General Physical Activities	Documenting/Recording Information	Inspecting Equipment, Structures, or Material	Evaluating Information to Determine Compliance with Standards
Handling and Moving Objects		Assisting and Caring for Others	Analyzing Data or Information
Controlling Machines and Processes		Operating Vehicles, Mechanized Devices, or Equipment	Interacting With Computers
Monitor Processes, Materials, or Surroundings		Repairing and Maintaining Mechanical Equipment	Drafting, Laying Out, and Specifying Technical Devices, Parts, and Equipment
Monitoring and Controlling Resources		Repairing and Maintaining Electronic Equipment	Scheduling Work and Activities
			Getting Information
			Making Decisions and Solving Problems
			Thinking Creatively
			Updating and Using Relevant Knowledge
			Developing Objectives and Strategies
			Organizing, Planning, and Prioritizing Work
			Identifying Objects, Actions, and Events
			Estimating the Quantifiable Characteristics of Products, Events, or Information
			Judging the Qualities of Things, Services, or People
			Processing Information
			Interpreting the Meaning of Information for Others
			Establishing and Maintaining Interpersonal Relationships
			Selling or Influencing Others
			Resolving Conflicts and Negotiating with Others
			Coordinating the Work and Activities of Others
			Performing Administrative Activities
			Staffing Organizational Units
			Communicating with Supervisors, Peers, or Subordinates
			Communicating with Persons Outside Organization
			Performing for or Working Directly with the Public
			Developing and Building Teams
			Training and Teaching Others
			Guiding, Directing, and Motivating Subordinates
			Coaching and Developing Others
			Provide Consultation and Advice to Others

Source: O*NET.