Do Information and Communication Technologies Empower Female Workers? Firm-level Evidence from Vietnam *

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Abstract

This paper examines how firm-level ICT adoption impacts female employment. Exploiting exogenous ICT capacity expansions in Vietnam's domestic backbone as instruments, we find that increases in firm-level ICT adoption lead to higher firm female labor share. Second, we find significantly larger impact of firm-level ICT adoption on female labor share in less routine and more social skill intensive service sectors. Additional analysis using household surveys reveals that after ICT expansions, female workers are less likely to be employed informally, and experience increases in both income and working hours. These findings underscore the potential of ICT infrastructure development in emerging economies to significantly boost female employment growth.

Keywords: Information Communication Technologies (ICT), Infrastructure, Gender Inequality

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1 Introduction

Since the 1990s, advances in information and communication technologies (ICT) across the world have substantially changed the way people live, work, and interact with each other. The ICT revolution has reduced the distance between individuals, lowering the costs of information acquisition and coordination of activities within and between firms. The resulting flows of knowledge and information over longer distance contribute significantly to economic, social, and cultural convergences across countries.

Another important global phenomenon is the rising income inequality within nations, despite a closing income gap between countries due to the catching up of several large emerging economies.[1] The rapid rise in within-country income inequality in many nations has drawn tremendous attention from both policy makers and academics.[2] Untamed rising income inequality was attributed as a major cause of the political and social unrests in non-democratic nations (Campante and Chor, 2012), as well as the rise of populism and political polarization in Western democracies (Autor et al., 2020). The increasing use of ICT, artificial intelligence, and robots in production, has received relatively less attention in the inequality literature.[3] Research on the interplay between ICT and labor demand within firms for different skill groups is even more sparse.

Our paper contributes to the inequality debate by studying how ICT affects female employment within firms. In contrast to the extensive literature that focuses on developed nations, we explore the research question using firm-level data from a large developing country, Vietnam. In particular, we examine how firm-level ICT adoption impacts female employment. As part of the national ICT expansions in Vietnam, firm access to the Internet drastically increased during our sample period, from 2004-2009. Our research design exploits exogenous capacity upgrades in Vietnam's main domestic backbone and submarine cables in 2007. To construct instruments for changes in firm-level ICT adoption, we interact firms' distance to the nearest node site on the terrestrial backbone with an indicator for years after 2007. The intuition follows the technological consideration that firms closer to the backbone benefit disproportionately more from major ICT capacity upgrades as connectivity decays exponentially with distance (Banerji and Chowdhury, 2013).

Our analysis exploits unique features of the Vietnamese annual enterprise census, which contain detailed measures of firm-level ICT adoption and female employment outcomes. This allows us to ex-

[1] According to Baldwin (2013), the seven emerging markets that replace the lost share of global manufacturing output of G7 countries are China, Korea, India, Turkey, Indonesia, Thailand and Poland.

[2] For example, Piketty's 700-page "Capital in the Twenty First Century" (Piketty's, 2014) has drawn global attention.

[3] Acemoglu and Restrepo (2020) is a notable exception. The authors find significantly negative effects of robots on employment and wages across US commuting zones.

amine not only reduced form impact of national ICT capacity expansions on female labor share, but various first-stage firm ICT adjustment margins. Additionally, we examine differential impact of ICT adoption on female employment across industries with varying task intensity. We demonstrate that our main results are robust to a rich set of sensitivity checks, such as the inclusion of a rich vector of firm-level covariates, regional business cycles, product demand shocks, firm fixed effects, alternative bandwidth choices, and two-way clustering. We complement firm-level analysis with household surveys in Vietnam to provide further details on the informal economy.

There are three main findings. First, increases in firm ICT adoption lead to higher firm female labor share. Our first stage estimates confirm that major national ICT capacity expansions increase firm-level ICT measures significantly more for firms located closer to the nearest backbone node site compared to those slightly further away.[4] In the second stage, we find that increases in firm-level ICT adoption raise female labor share. By several measures of firm-level ICT, this positive relationship is robust and significant. On the intensive margin, a 10% increase in the number of personal computers (PC) connected to the Internet per worker increases the female labor share of the firm by 2 percentage points. This is equivalent to 6% over the 33.7% baseline share of female labor share for Vietnamese firms in our sample. Similarly, a 10% increase in the number of personal computers (PC) connected to LAN per worker increases the female labor share of the firm by 2.8 percentage points.

Our second finding highlights the differential impact of ICT adoption on firm female labor share across sectors with varying task intensity, and illuminates the underlying mechanism. We first document strong gender sorting along the routine and social task intensity dimensions in the service sectors. Access to broadband Internet shifts firm production towards more flexible job designs (Bartel et al., 2007). Aligning with females' comparative advantage in "brain" versus "brawn" tasks, and social skill intensive sectors, we show that among service firms, improved firm-level ICT adoption increases female employment share in less routine and more social skill task intensive sectors.

The third set of results complement our main firm-level analysis using data from the Vietnam Household Living Standard Surveys (VHLSS), providing details on the informal economy and a richer set of outcomes. We find the workers living closer to the nearest node site experience a larger reduction in self-employment and informality share, and a larger increase in working hours and income, after the ICT expansions. The effects are more statically significant and larger in magnitude for female workers. Additionally, we find that female workers closer to the nearest nodes are more likely to engage in occupa-

[4]The first stage IV results are strong with Kleibergen-Paap F statistics significantly above 10.

tions which require less manual and more social skills. This result corroborates our earlier findings from firm-level data, showing that female workers gain from ICT expansions, specializing in occupations that are more social skills intensive, where they have a comparative advantage.

This paper contributes to several strands of literature. First, there is a rich literature on the impact of ICT on labor market outcomes (Autor et al., 1998; Crandall et al., 2007; Forman et al., 2012; Michaels et al., 2014), but few focuses on female employment. Using Norwegian firm-level data, Akerman et al. (2015) show that broadband Internet improves the labor market outcomes and productivity of skilled workers. In Africa, the Internet is found to have significantly contributed to declines in job inequality between less educated and more educated workers (Hjort and Poulsen, 2019). Our study relies on similar IV designs as Akerman et al. (2015) and exploits exogenous variations from major ICT capacity expansions. However, we diverges from previous work in our focus on Vietnamese firm-level female employment share, as well as female workers' working hours and occupational choices, motivated by gender differences in comparative advantage.

Second, our work also contributes to the literature on technological change, tasks, and gender inequality, which has mostly focused on developed countries (Autor et al., 2003; Aksoy et al., 2021; Beaudry and Lewis, 2014; Black and Spitz-Oener, 2010; Cortés et al., 2024; Greenwood et al., 2016; Kwon, 2022; Ngai and Petrongolo, 2017; Olivetti and Petrongolo, 2016; Vidart, 2024).[5] Juhn et al. (2014) is the only paper that we are aware of that links technological changes to gender inequality for a developing country.[6] Unlike Juhn et al. (2014) which focuses on machinery upgrading caused by trade liberalization, we exploit exogenous variations from major ICT capacity expansions in Vietnam. Compared to the "bartik-style" instruments used to proxy for technological change in previous work, our data and approach offers direct measures of firm-level ICT adoption along various dimensions. We find that firm female labor share increases across the board, with more pronounced impact in less routine, more social task intensive sectors. Additionally, by combining data from both household and firm surveys, we are able to explore the influence of ICT on female labor market outcomes in the informal sector—a critical consideration for developing economies.

Third, our paper is also related to the literature on labor market returns to social skills. Previous work shows that "non-cognitive" skills are valued in the labor market (Heckman et al., 2006; Borghans et al., 2008; Lindqvist and Vestman, 2011). Deming (2017) develops a team-production model, which

[5] See Goldin (2006) for a discussion about the economic, sociological and political factors behind the trends of female labor market performances in the U.S. of the 20th century.

[6] They find evidence that the relative wage and employment of women in Mexico improved primarily in blue collar jobs due to increased computerization, as it lowered the demand for physically demanding tasks.

predicts increases in the return to social skills with an increase in non-routineness, for example, as ICT expansions shift jobs toward more flexible designs (Autor et al., 2003; Bresnahan et al., 2002; Bartel et al., 2007). Our paper extends these insights to study gender-specific employment outcomes in the context of Vietnam's ICT expansions. Females have comparative advantage in more "brain" versus "brawn" type of jobs, and in emotional and social cognition (Welch, 2000; Schulte-Rüther et al., 2008; Rueckert and Naybar, 2008; Rendall, 2017). Consistent with these intuitions, we found that firms ICT adoption not only increases female labor share, but differentially more so for firms in service sectors that are less routine, and requiring more social skills. The results imply that higher job flexibility combined with lower cost in "task trade" (Deming, 2017) is a potential channel through which ICT could increase firm-level female labor share in developing countries.

The paper proceeds as follows. Section 2 outlines the institutional context and the construction of the instrumental variable (IV). Section 3 introduces the data and empirical facts. Section 4 discusses the conceptual framework. Section 5 details our identification strategy and firm-level results. Section 6 presents further analysis using household surveys. Section 7 concludes.

2 Internet Expansion and Gender Differences in the Labor market

2.1 Institutional Background

A relative late adopter of the Internet, the Vietnam government identified widespread, low cost access to Information and Communication Technology as essential following a broader set of economic reform goals under its "open door" (Doi Moi) policy of the late 1990s. In 1992, an experimentation of Vietnam's first national computing network were carried out by collaborations between Hanoi's Institution of Information Technology (IOIT) and Australian National University. The foundation of Internet in Vietnam was the Vietnam Academic Research and Education Network (VARENet), built in 1994 to facilitate exchanges of academic communication and research. After rolling out a series of provisional regulations, Internet services were first provided to commercial users in the late 1990s.

The national optic fiber backbone was constructed by the Vietnam Telecom National (VTN), a member of the Vietnam Post and Telecommunications Group (VNTP). Figure A.1 illustrates the early terrestrial backbone and node sites in Vietnam, according to the Transmission Network Data from the International Telecommunication Union (ITU). As shown in the map, the national backbone network with ring topology consists of fiber optic transmission systems connecting Hanoi to Ho Chi Minh City, as well as

regional networks in the North, Northeast, Central regions and the South.

Although officially approved for public access, Internet penetration and bandwidth remained low in the early 2000s due to high cost and limited optic transmission capacity. In 2005, access to the Internet in Vietnam was still poor, with only 210,000 fixed broadband subscriptions and international bandwidth around 3 Gbps (Tuan, 2011). Starting from 2007, rapid capacity expansion and technological upgrades of the telecommunications sector has created vast improvements in access to ICT in Vietnam. A series of policies that provided for joint ventures opened the path to competitiveness bringing ICT investments and protocols that were in line with global standards, increasing speed, expanding access, and driving down prices. In a little over a decade, Vietnam's strategic investments have transformed it from a Southeast Asian laggard to a leader in technological competitiveness.

The year 2007 marks two major technological improvements that started significant expansion of ICT capacity in Vietnam. First, Vietnam's main submarine cable, SEA-ME-WE 3, went through the 10G capacity upgrades in 2007. This submarine cable directly connected Vietnam with East Asia, South East Asia, Africa, Europe and Oceania, landing in 33 countries. This upgrade, the first major capacity expansion since SEA-ME-WE 3 first landed in Vietnam in 1999, significantly improved quality and speed of access. In the same year, the domestic terrestrial backbone also implemented major capacity expansions. According to the Vietnam Post and Telecommunications Group, Vietnam's main Internet Service Provider, this capacity upgrade was crucial to provide ADSL broadband access to more residential and enterprise customers. In addition, Vietnam joined the WTO in 2007, which complemented improvements in ICT infrastructure by substantially reducing the costs of importing various ICT equipment.

As a result of these major capacity upgrades, both domestic and international bandwidth in Vietnam went through drastic improvements since 2007, according to data from the Vietnam Internet Network Information Center (VNNIC, 2013). As shown in Figure 1, both domestic and international bandwidth experienced sluggish growth in the early 2000s, with dramatic expansions after 2007. International bandwidth increased from 3615 Mbps in 2005 to over 400 Gbps in 2013. By 2011, ICT provision was competitive with 90 different Internet providers and 5 companies offering cellular data (Tuan, 2011). By 2015, as shown in Table A1, average bandwidth in Vietnam had risen to more than 24 thousand bits per second per person, with entry level plans available for only $3 per month. This makes it extremely affordable for firms and individuals to increase their Internet use. In our empirical specification, we exploit this exogenous, unprecedented Internet capacity expansion in Vietnam due ICT-related technological improvements in a quasi-experimental design.

2.2 Instrumental Variable Construction

The Vietnam Enterprise Surveys during our sample period (2004-2009) have a module which records firm ICT adoption. However, firm-level ICT adoption are likely to be endogenous or simultaneously driven by other firm-level unobservables. Motivated by the institutional settings described in Section 2.1, our empirical design takes an instrumental variable approach, where we use distance from the firm's location to the nearest node site on the main terrestrial backbone to measure firm's exposure to Internet capacity expansions in Vietnam after 2007. Technological considerations suggest that connectivity decays exponentially as one moves further away from the backbone (Banerji and Chowdhury, 2013). A number of studies in the literature leverage proximity to Internet infrastructure to provide exogenous variations in firm or individual's ability to benefit from lowering ICT costs (Bloom et al., 2014; Forman et al., 2012; Hjort and Poulsen, 2019; Jiang, 2022).

We exploit the timing of significant optic cable capacity upgrades and the differential impact on firms closer versus farther away from the terrestrial backbone node sites. Our instrument $log(DistanceToNode_i) * Post2007_t$ is constructed by interacting each firm's distance from the nearest node, with a dummy variable taking the value of one for years after 2007. To calculate firm's distance from the nearest node site, we georeference and digitize a historic terrestrial backbone map layer for Vietnam, provided by the Interntaionl Telecommunication Union's Transmission Network Data.

Although the Vietnam Enterprise Surveys do not have the exact coordinates of firms, we are able to locate the province (*tinh*), district (*huyen*) and commune (*xa*) of firms using concorded geographic identifiers. We implement a python program to extract firm commune coordinates matching three levels of administrative names in Google Map's Geocoding Platform. For a small number of mismatched communes, we manually correct the coordinates. Figure 2 illustrates the digitized terrestrial backbone node sites *in red* and firms' Vietnamese communes *in blue* according to the Vietnamese Enterprise Surveys. We then calculate the distance between each firm's commune centroid and the nearest node sites to construct our instrument. In our main specification, we exclude locations that are more than 20 kilometers from the nearest backbone node, to make sure we are comparing firms with similar trends before 2007.

Table 1 provides more summary statistics on our IV construction. There are 96492 unique firm IDs in the Annual Enterprise Census from 2004-2009, dispersed in 64 provinces, 665 districts, and 6989 communes. Around 87% firms are located within 20 kilometers from the nearest terrestrial backbone node site. In our main specification, we exclude firms located in communes further than 20 kilometers away from the backbone, to make sure we are comparing firms in similar locations. We test sensitivity to using

alternative exclusion thresholds as robustness checks.

2.3 Gender Differences in the Labor Market

Against the backdrop of changing ICT is a labor market with relatively minimal differences in labor market participation, but gender differences that operate through employment and wage outcomes. According to Vietnam's Labor Force Surveys, in 2013, 85% of males and 77% of females ages 15-64 were participating in the labor force (Appendix A, Table A.3). Gender wage gaps have declined between 2007 and 2013, particularly among workers with lower levels of education, but men continue to make about 15-30 percent higher wages (Appendix A, Table A.2). Like many developing countries, the informal sector characterizes a large proportion of the population and female workers are less likely to participate in formal wage work at 30% compared to 40% of males. ICT could play an important role in closing gender gaps in employment outcomes if firm-level adoption improves the relative returns to tasks in which females have comparative advantage, inducing firms to offer higher wages and more stable employment. One of the major changes ICT brings to the labor market is increasing return to nonroutine and social skill intensive tasks. These changes potentially increase women's employment opportunities since females have comparative advantage in tasks with flexible job designs (Cortes and Pan, 2018).

3 Data and Descriptive Statistics

3.1 Firm-level Data

Firm level data come from the Annual Enterprise Census of Vietnam, over the period of 2004-2009, conducted by the General Statistics Office of Vietnam (GSO). The annual censuses cover all enterprises, across both manufacturing and non-manufacturing sectors, with state-owned, collectively owned, private and foreign enterprises. The enterprise censuses contain detailed balance-sheet information of each firm. For example, each firm's total employment, employment by skill and gender, capital, revenue, expenses, profits, liabilities, and most importantly, adoption of various ICT measures are reported.

A unique aspect of the Vietnamese enterprise census is its comprehensive and detailed information on firm-level ICT adoption. Specifically, the censuses provide details on each firm's usage of personal computers, usage of LAN and access to the Internet. Table 3 reports summary statistics on various firm-level ICT variables use in our analysis. 2004 is the first year in our sample, where firm-level Internet

penetration is around 49%. By 2009, Internet penetration reached 85% of all firms in the sample.[7] Figure 3 illustrates that firm-level ICT adoption, measured in the following four ways, experienced significant increases during our sample period:: log number of PCs per worker, log number of PCs connected to the Internet per worker, log number of PCs with LAN per worker and the fractions of firms having internet access. We explore all four measures of firm-level ICT adoption in our main analysis.

Figure 3 plots the relationship between firm-level female labor share and measures of ICT adoption in the raw data. The left panel shows that female labor share increases with higher firm-level measure of PC per worker. Similarly, in the right panel, we also observe a positive correlation between the number of PC with internet per worker and firm female labor share. There are many other observed and unobserved variables that correlate with both female labor share and firm-level ICT measures. To causally identify the impact of ICT adoption on firm female employment, we adopt an instrumental variable approach, exploiting exogeneous variations provided by major ICT capacity expansions in Vietnam.

3.2 Household-level Data

To complement our firm-level analysis and shed light on the informal economy, we also use household-level data from the Vietnam Household Living Standard Survey (VHLSS), from 2002 to 2012.[8] The household surveys are nationally representative and contain workers in all industries. The surveys report worker demographic characteristics including gender, age, education, marital status, sector and geographic location (province, district and commune). In addition, the labor force component of these surveys records whether a worker works for the registered enterprise (formal) sector or for the household business (informal) sector. Similar data sources have been used in McCaig and Pavcnik (2018) to study the effect of trade liberalization on labor allocation.[9]

3.3 Other Data

We obtain Vietnam's historic terrestrial backbone maps from the International Telecommunication Union. We construct various task intensity measures at the Vietnamese industry-level to examine differential impact of firm-level ICT adoption on firm female labor share across industries. Task intensity measures in routine, manual, and social aspects come from Autor et al. (2003) and Deming (2017). These task inten-

[7] Note that for 2006, the GSO of Vietnam did not report information on firms' ICT in their surveys.
[8] The VHLSS are available every two years, so we use data from the years 2002, 2004, 2006, 2008, 2010 and 2012.
[9] We follow McCaig and Pavcnik (2018) and McCaig and Pavcnik (2021) to clean individual and household identifiers.

sity measures were originally defined at the US Census occupational level using the US Department of Labor's Occupational Information Network (O*NET) data. We then use industry-occupational compositions from the 2000 American Community Surveys (ACS) to construct task intensity measures at the US Census industry level. This data is collapsed to 3-digit NAICS codes and mapped to the International Standard Industry Classification codes (ISIC rev 4.4), using concordance files from the website of the United Nations Statistics Division.[10] We are able to construct these task intensity measures for Vietnam under the assumption of no factor intensity reversal. In our data, administrative activities, repair of machinery and manufacturing are the most routine intensive in Vietnam. Industries that require more social interactions include food services, social work, and retail services.

4 Conceptual Framework

In this section, we outline a conceptual framework that provides a guide for understanding the interplay between firms' demand for tasks, ICT adoption, and employment by skill and gender groups. To this end, we borrow the key features and assumption of the task model of Autor et al. (2003) and Tang and Zhang (2021). Intuitively, we expect ICT to complement non-routine and more customized production (Bartel et al., 2007; Deming, 2017), and that female workers have comparative advantages in "brain" intensive tasks. Consequently, we operate under the following assumptions:

A1. ICT adoption shifts production towards more flexible, nonroutine job designs.

A2. Social skills complements non-routine tasks.

A3. Female workers have a comparative advantage in "brain" (versus "brawn") tasks, and social skill intensive sectors.

Making the same set of assumptions, we can expect that an increase in ICT adoption by firms will reduce their relative demand for routine (social) tasks but raise their relative demand for non-routine (less social skill intensive) tasks. What is new in our framework is that we have workers differentiated by gender in terms of their comparative advantage in different tasks. Existing empirical research provides direct and indirect evidence that females have a comparative advantage in non-routine, social skill intensive tasks. ICT has led to a relative increase in the complementary value of social skill intensive, service oriented tasks compared to tasks that require little interaction (Black and Spitz-Oener, 2010). More recently, Deming (2017) illustrates an additional channel using a model of trade-in-task where work-

[10] https://unstats.un.org/unsd/cr/registry/regot.asp?Lg=1

ers with higher social skills sort into nonroutine occupations. As ICT adoption replaces routine tasks and increases the variance of productivity, relative returns rise for workers who are better endowed with social skills. Thus, we can relate a higher complementary value between ICT and non-routine, customer-oriented tasks in which females have a comparative advantage to ICT. With the assumption of this mapping, we have the following testable hypothesis.

Hypothesis 1

All else equal, a firm's adoption of ICT has a positive effect on the share of female employment if ICT is more complementary to non-routine, social skill intensive tasks for which females have a comparative advantage.

5 Firm-level ICT Adoption and Female Employment

We identify the effect of firm-level ICT adoption on firm female employment using an instrumental variable approach. We first present OLS results. Firm-level ICT adoption could be correlated with unobservables such as time-varying managerial ability or other determinants of firm productivity. Second, to address possible concerns of endogeneity, we exploit exogenous expansions in ICT capacity. In 2007, Vietnam's main domestic terrestrial backbone and submarine cables both went through major capacity upgrades, significantly increasing the speed of Internet transmission services. As described in section 2.2, we exploit the differential effect of major cable capacity upgrades from Vietnam's WTO for firms closer to, versus further away from the national backbone node sites. Our instrument $log(DistanceToNode_i) * Post2007_t$ is constructed by interacting each firm's distance to the nearest backbone node, with a dummy variable taking the value of one for years after 2007. Technical considerations suggest connectivity decays exponentially as one moves further away from the backbone (Banerji and Chowdhury, 2013). Intuitively, firms closer to node sites benefit more from ICT capacity expansions since they get better connectivity if choosing to adopt ICT.

5.1 OLS Estimation

To estimate the effect of increasing firm-level ICT adoption on firm female employment share, we first examine the baseline OLS specification

$$Y_{it} = \alpha + \beta_1 ICT_{it} + \tau X_{it} + \gamma_i + \theta_t + \epsilon_{it} \tag{1}$$

The outcome variable, Y_{it}, stands for firm i's share of female workers among total employment in year t. The main independent variable, ICT_{it}, is one of the following three measures of firm-level ICT adoption: (1) log number of PCs per worker (2) log number of PCs connected to Internet per worker (3) log number of PCs connected to local area networks (LAN) per worker. X_{it} is a vector of firm-level covariates, including firm age, foreign ownership dummy, state ownership dummy, sales, fixed asset and employment. We also add year and firm fixed effects. Standard errors are clustered at the firm level.

We report the OLS estimates in Table 4 to show the correlation between firm-level ICT and shares of female employment. Across all three measures of firms' ICT adoption, we find a positive and statistically significant correlation between firms' ICT and female labor share. The positive correlation is robust after we control for the firm's log sales, log asset, log employment, age, foreign ownership dummy, state ownership dummy, year and firm fixed effects. In the appendix, Table A.5 shows that our OLS results are robust when we exclude locations that are more than 20km from the nearest node. However, as discussed in the previous section, our OLS estimates are likely to be biased due to omitted variables such as time varying firm managerial quality, and other unobserved determinants of firm productivity.

5.2 Two-stage Least Squares Estimation

OLS estimates are likely to biased, however, if there exists firm-level omitted factors that are also time varying. For example, changes in firm productivity and managerial capability are likely to be correlated with both technological and ICT adoption and the relative demand for female workers. To address omitted variable bias and other concerns of endogeneity, we take an instrumental variable approach and implement two-stage least squares estimation. The exclusion restriction requires that our instrument only influences firm female labor share through firm-level ICT adoption, and is not correlated with other omitted unobservables. The first stage of our two-stage least squares estimation is specified as follows:

$$ICT_{it} = \beta_1 log(DistanceToNode_i) * Post2007_t + \beta_2 log(DistanceToNode_i) + \tau X_{it} + \gamma_i + \theta_t + \epsilon_{it} \quad (2)$$

The outcome variable in the first stage, ICT_{it}, measures firm i's ICT adoption in year t. We instrument for ICT_{it} using $log(DistanceToNode_i) * Post2007_t$, interacting the log of firm i's distance to the nearest node site in year t with a dummy variable taking the value of one for years after 2007. We control for the main effect of firm's distance to the nearest node, $log(DistanceToNode_i)$. This ensures that our main results will not be driven by firm characteristics that correlate with their initial spatial distribution. Similar to Equation 1, X_{it} is a vector of firm-level covariates, including firm age, foreign ownership dummy, state ownership dummy, sales, fixed asset and employment. We also control for year and firm fixed effects. Standard errors are clustered at the firm level.

We exclude locations that are more than 20km away from the nearest backbone node site. Our identifying assumption is that firms close to and slightly further away from the nearest backbone node sites were on parallel trends in female labor share before the major cable capacity upgrades in 2007. The exclusion restriction is that there is no idiosyncratic shock that differentially impacts firm female labor share through firm-level ICT adoption, other than the ICT expansions in 2007. Intuitively, our instrument allows us to isolate the temporal and spatial variations in firm-level ICT measures driven by exogenous ICT expansions and firms' relative location to the nearest nodes.

To ensure that firms with different distances to backbone nodes are comparable on key characteristics prior to the intervention, we perform a balance check in Table 2. Since we control for firm fixed effects, it is important to verify whether there are any significant differences in the changes of firms' characteristics based on their distance to nodes. Columns 1 and 2 display the summary statistics for the overall sample, while columns 3 and 4 show the summary statistics for the pre-treatment sample (2004-2006). We calculate the trends (long differences) in each firm's characteristics from 2004 to 2006 and test the correlation between these trends and the distance to the nodes. Column 5 indicates that there is no significant correlation between the trends and distance for any of the firm-level characteristics.

Table 5 presents our two-stage least squares estimates. We use $log(DistanceToNode_i) * Post2007_t$ as the instrument for firm-level ICT. Intuitively, this allows us to compare changes in female labor share for firms close to versus slightly further away from the nearest node, before and after the ICT expansions in 2007. The first stage regressions isolate exogenous variations in firm-level ICT adoption using the instrument. Focusing on the lower panel, the coefficients on the instrument are negative and significant.

This suggests that ICT expansions in 2007 increase firm-level ICT adoption significantly more, for firms closer to the domestic backbone node sites. Notice that corresponding Kleibergen-Paap F statistics of the first stage are significantly above 10[11], indicating that our instrument passes the weak IV test.

Turning to the second stage outcomes in the upper panel, across all three ICT measures, we see that an increase in firm ICT adoption leads to higher firm female labor share, with slightly larger magnitudes. Column 1 shows that a 10% increase in the number of personal computers (PC) connected to the Internet per worker increases the female labor share of the firm by 1.9 percentage points. The effect of having more computers with connections to Local Area Network (LAN) is larger. Based on column 2, a 10% increase in the number of personal computers (PC) connected to LAN per worker increases the female labor share of the firm by 2.6 percentage points. The effect of having more personal computer per worker is also positive and significant. ICT capacity expansions led to firm-level ICT adoption, which differentially increases the return to tasks in which females have comparative advantages.

We also conduct an event-study framework to test for pre-trends, as follows:

$$Y_{it} = \beta_t \log(DistanceToNode_i) \times Year_t + \beta_2 \log(DistanceToNode_i) + (\tau X_{it}) + \sigma_i + \theta_t + \epsilon_{it} \quad (3)$$

where Y_{it} represents our main outcome of interest, female labor share. Compared to our main specification in equation (2), we interact $\log(DistanceToNode_i)$ with dummy variables for each year, rather than using a single dummy for years post-2007. Table 5 plots the coefficients of the interaction between $\log(DistanceToNode_i)$ and the year-specific dummy variables, β_t. Panel A shows the results without controlling for firm-level characteristics, while Panel B presents the results with firm-level controls. We find no significant effects of $\log(DistanceToNode_i)$ on female labor share before 2007, suggesting the absence of significant pre-trends.

For our main results in Table 5, we exclude locations that are more than 20km from the nearest domestic backbone node site, to make sure we are comparing firms with similar trends in female labor share before 2007. We conduct several robustness checks in the Appendix. In Table A.6, we show that our results hold in alternative specifications that control for urbanization trends (by adding the interaction of distance to the city center and year), population growth, and globalization (by including industry-year fixed effects). This shows that our results are not being driven by industry-specific product demand

[11] which is the "rule of thumb" cutoff proposed by Stock and Yogo (2005)

shocks nor local business cycles. In Table A.7, we show that our IV results are also robust to varying location restrictions, and hold when comparing similar firms within narrow spatial bands around the backbone nodes. Finally, we test robustness to an alternative clustering strategy, where the standard errors are clustered two way, at the firm, and at the commune-by-year level. Results remain similar, as shown in Table A.8.

5.3 Differential Impact Across Industries

Why do ICT expansions increase firm female labor share? We hypothesize that ICT adoption in firms changes the production process and increases the relative return to tasks where females have comparative advantage. To provide evidence for this, we examine the differential impact of ICT adoption on firm female labor share across industries with varying task intensity and discuss potential mechanisms.[12]

Evidence in the literature suggests that information and communication technologies (ICT) complement workers in nonroutine, information intensive tasks (Akerman et al., 2015; Autor et al., 2003; Goos et al., 2014; Michaels et al., 2014). Deming (2017) illustrates that social skills are increasingly valued in the US labor market as task nonroutineness increases. In a developing country context, we link these changes in job designs brought by ICT adoption to changing gender roles in the labor market. Females have comparative advantage in more "brain" instead of "brawn" type of jobs (Rendall, 2018; Welch, 2000). In terms of social skills, studies in neuroscience document that females frequently score higher on standard tests of emotion recognition and social sensitivity associated with gender specific neural mechanisms of emotional and social cognition (Cortes and Pan, 2018; Rueckert and Naybar, 2008; Schulte-Rüther et al., 2008).

Before providing formal estimation results, we first examine differences in gender sorting by occupational task intensity in the raw data. First, sectors with highest requirement in social skills include food services, retail services, movie activities, facilities support and consulting services, while manufacturing sectors have the lowest requirement in social skills (Table A.9). Overall, the positive correlation between social task intensity and female labor share at the firm-level is statistically significant at the 1% level. (Table A.10). Second, gender sorting patterns by task intensity differ by sectors. Using Vietnamese firm-level data, we plot gender sorting patterns along both the routine and social task intensity measures.

[12]The ideal evidence for this would be at the occupation level. However, only industry codes are available in the Vietnam Enterprise Surveys. Under the assumption of no factor intensity reversal, we construct industry-level proxies for task intensity following procedures described in Section 3.3.

Panel A of Figure 6 plots the raw correlations between industry (ISIC Rev4) level average female labor share and social task intensity in 2007, for manufacturing sectors. We do not observe a statistically significant sorting pattern. Panel B of Figure 6 plots the same relationship in the raw data for service sectors. We see that industries requiring more social skills have significantly higher average female labor share. This provides suggestive evidence that female workers sort into social task intensive industries where they have comparative advantage, but only in service sectors. Similarly, figure 7 shows that female workers sort into less routine task intensive industries in services, but not in manufacturing. In services, gender sorting along the routine task intensity dimension are statistically significant at the 10% level.

Given the revealed gender sorting patterns by occupation in different sectors, we then investigate how ICT expansions affect firm-level female labor share. As firm ICT adoption complements nonroutine, customer-oriented tasks and biases job designs towards social skill intensive settings for which females have comparative advantage, we would expect to see differential impact across industries with varying task intensity. To provide suggestive evidence for our proposed mechanism, we estimate the modified two-stage least squares specification. Our framework allowing for interaction with industry-level task intensity is as follows:

$$\begin{aligned} Femaleshare_{it} = {} & \beta_1 log(DistanceToNode_i) * Post2007_t \\ & + \beta_2 log(DistanceToNode_i) * Post2007_t * T_j + \beta_3 log(DistanceToNode_i) \\ & + \beta_4 T_j + \tau X_{it} + \sigma_i + \theta_t + \epsilon_{it} \end{aligned} \quad (4)$$

The outcome variable, $Femaleshare_{it}$, measures firm i's female labor share in year t. Compared with equation 2, we allow for an additional interaction term between firm level ICT adoption, ICT_{it}, and a dummy variable for industry-level task intensity measure, T_j. T_j takes the value of one if industry j's task intensity is above median among all industries and zero otherwise. In the first stage, we use both $log(DistanceToNode_i) * Post2007_t$ and $log(DistanceToNode_i) * Post2007_t * T_j$ as instruments. Industry-level task intensity measures are constructed based on steps in section 3.3. In addition, we control for the main effects of firm's distance from backbone $log(DistanceToNode_i)$, industry-level task intensity T_j, a vector of firm-level covariates X_{it}, as well as year and firm fixed effects.

We first examine how the impact of ICT expansions and firm ICT adoptions, measured by access to the Internet, differs across industries along the routine dimension. Table 7, column 1 in Panel A and

Panel B presents estimates. We see a negative and significant coefficient on the interaction term for Panel A - firms in services, where we also observe strong gender sorting by routine task intensity (Figure 7). This suggests that among services firms, gaining access to the Internet at the firm-level increases female labor share in less routine industries. Access to broadband Internet is shown to bias firm production process towards more flexible job designs and increases returns to nonroutine activities (Akerman et al., 2015; Black and Spitz-Oener, 2010). Bartel et al. (2007) provide evidence that IT investment supports the change in business strategy to more customized production, increases the requirement of problem solving skills and increases the adoption of new human resource practices. Females have comparative advantage in these settings because of their relative strengths in "brain" intensive tasks. In nonroutine industries where the task complementarity with ICT is stronger, relative returns disproportionally rise. We therefore expect larger increases in firm female labor share in these industries.

Closely related to the rise of female labor share in nonroutine industries following firm ICT adoption is the rise of female labor share in social skill intensive industries. We focus on results in column 3-5 of Table 7. Along various measures of social task intensity, we observe positive and significant estimates on the interaction terms with firm ICT adoption, for Panel A but not Panel B. This is consistent with Figure 6, where we show that strong gender sorting by social task intensity is significant in services, but not manufacturing. This implies that among service sector firms, the positive impact of gaining access to the Internet on firm female labor share is on average larger in industries requiring more social skills. The increase in female labor share after ICT expansion is also larger for industries that are more customer and service oriented.

Deming (2017) illustrates using a model of trade-in-task that workers with higher social skills sort into nonroutine occupations. As ICT adoption replaces routine tasks and increases the variance of productivity, relative returns rise for workers who are better endowed with social skills or lower "trade costs". Evidence from neuroscience and social psychology documents that females frequently score higher on standard tests of emotion recognition and adopts a different neural mechanism of social cognition (Rueckert and Naybar, 2008; Schulte-Rüther et al., 2008). Guiso et al. (2008) find that girls on average score higher in reading tests. Without assuming patterns of absolute advantages in social skills across gender groups, women have comparative advantage in skills related to communication and social perceptiveness which are complemented by firm ICT adoption, relative to manual and routine activities. As returns to interactive tasks where women have comparative advantage rise more in customer and communication-oriented industries such as consulting, healthcare, and legal services, we observe a pos-

itive estimate on the interaction term with industry-level social skill intensity.

6 Household-level Outcomes

Although the Enterprise Census allows us to directly observe firm-level ICT adoption, it does not provide data on income by gender, nor does it cover the informal sectors. Similar to many other developing countries, the informal economy in Vietnam represents the larger share of overall employment (McCaig and Pavcnik, 2018). Women are also less likely to participate in formal wage work at 30% compared to men at 40%. In this section, we complement previous firm-level analysis using household-level data from the Vietnam Household Living Standard Survey (VHLSS). The purpose is to shed light on the impact of ICT on additional outcomes such as income, employment status, and propensity to be employed in the informal sectors. We directly estimate the reduced form specification in Equation 4.

$$Y_{it} = \alpha + \beta_1 log(DistanceToNode_i) * Post2007_t + \alpha_r + \theta_{it} + \epsilon_{it} \tag{5}$$

The outcome variable, Y_{it} denote individual i's labor market outcomes in year t. Our key independent variable, $log(DistanceToNode_i) * Post2007_t$, is the log of individual i's distance to the nearest backbone node, interacted with a dummy variable taking the value of one for years after 2007. θ_{it} denotes individual level covariates such as age and marital status. We also control for commune fixed effects and year fixed effects.

We first present results on income and employment status in Table 8. Similar as before, we exclude locations within 20km from the nearest backbone nodes, so that households within our sample are subject to comparable geographic and economic trends. Column 1 and 2 present estimates on log real income, for female and male. The estimate from column 1 is negative and significant, suggesting that the ICT expansions in 2007 increase female worker income more when they live closer to the nearest backbone node site. The estimate for male worker wages are also negative and significant, with a smaller magnitude.

Column 3 and 4 present the estimates on employment status, where the dummy variable takes a value of one if employed and zero otherwise. Column 3 suggests that ICT expansions increase female employment more, if the worker locates closer to the nearest backbone node. The same pattern holds for male worker employment status, though imprecisely measured. Relative magnitude on the estimates by

gender suggest that the effect of ICT and employment status is differential larger for female workers.

Table 9 presents results on self-employment and informality. Column 1 and 2 show the estimates on whether the individual is self-employed in an agriculture, production or service sector. A positive estimate indicates that workers closer to the domestic backbone node experience a larger reduction in self-employment share after the ICT expansion. Comparing Column 1 to Column 2, we see that the estimates for female workers are positive and significant, whereas the estimate for male workers is smaller and not significant. This indicates that female workers experienced a larger drop in self-employment share after the ICT expansions.

Column 3 and Column 4 in Table 9 presents results on informality, where a worker is considered informal if he or she works for a household business, similar to McCaig and Pavcnik (2018). We see that the drop in informality for female workers living closer to the nearest domestic backbone node is larger and more significant. Together with results on employment from Table 8, we see that ICT expansions lead to increases in female employment but decreases in informality. This indicates possible labor reallocation from the informal to formal sectors for female workers, consistent with higher returns from ICT adoption in the formal sectors.

In Table 10, we present estimates on hours of labor supply per day, as well as total household expenditure. Column 1 and Column 2 measure the log of total number of hours spent working per day, by gender. The estimate for Column 1 is negative and significant, indicating that female workers living closer to the nearest backbone node increase their working hours more after the ICT expansion. Column 2 shows the estimate for male workers is positive and insignificant, indicating a muted effect on male workers. Column 3 presents results on the log of total household expenditure in real terms. We see a negative and significant estimate, suggesting households experienced larger gain in real expenditure if they live closer to the nearest node, after the ICT expansions.

Additionally, the Vietnamese household surveys provide detailed occupational codes, which allow us to also examine how Internet capacity expansions affect occupational choices by gender. We concord occupational codes in the VHLSS across years to the 1990 US census occupational codes constructed by Dorn (2009), which can then linked to ONET occupational task intensity measures from Autor et al. (2003) and Deming (2017). Using household occupational task intensity measures as the outcome variables, we can then examine the impact of ICT expansions at the individual-level.

Table 11 presents the estimates. Column 1, 3, 5, 7 focus on the impacts on female members of the households. We see that the after the ICT expansions, female workers living closer to the nearest back-

bone nodes are more likely to engage in occupations which require less manual, and more social skills. The impacted female workers are also more likely to be doing more customer and service-oriented tasks. In contrast, these effects are less significant for male workers, with much smaller magnitudes.

Women have a comparative advantage in social and emotional perceptiveness (Cortes and Pan, 2018). As ICT complements and increases the return to tasks intensive in social skills and customer orientation, female workers living closer to the network nodes benefit from the ICT expansion and specialize more in social skill intensive occupations. These results are consistent with earlier firm-level results using the enterprise surveys, and lend additional support to the key mechanisms at work.

7 Conclusion

In this paper, we study the effects of firms' investments in information and communication technologies (ICT) on their demand for female labor. Exploiting exogenous expansions in ICT capacity in Vietnam in 2007 and firms distance to the nearest backbone node site as instrument, we find that firms' adoption of broadband Internet and other related ICT measures increase relative demand for female labor. The positive effect of ICT on firms' female employment is stronger in service industries that are less routine and more social skill intensive. These results are consistent with the mechanism that rising relative demand for non-routine, social skill intensive tasks for which females have comparative advantages led to increases in firm female labor share.

Additionally, we complement our firm-level analysis with individual-level data from the Vietnamese Household Living Standard Surveys. We show that the ICT expansions disproportionately increase female employment, real income and lower informality. Our analysis also indicates that after ICT expansions, female workers closer to the nearest node sites tend to specialize in occupations demanding more social skills, aligned with our firm-level results.

Our findings based on firm survey data show that within firms, changes in labor demand are an important factor in reducing employment inequality along the gender dimension. For policy makers concerned with providing greater opportunities for females to enter the labor market and secure more stable employment in formal sector firms, implementing programs that induce firms' adoption of ICT can potentially stimulate female employment growth. Moreover, given the positive effects of ICT on firm productivity, these type of policies may produce greater effects on the growth of high quality employment.

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Table 1: FIRM DISTANCE TO NEAREST DOMESTIC BACKBONE NODE SITE

	Total
Number of Provinces	64
Number of Districts	665
Number of Communes	6989
Number of firms located within 15kms from the backbone	75079
Number of firms located within 20km from the backbone	84429
Number of firms located within 25km from the backbone	89182
Number of firms located above 25km from the backbone	7310
Number of firms	96492

Notes:

Table 2: BALANCE CHECK: SUMMARY STATISTICS BY DISTANCE TO NODES, PRE-TREATMENT

	Summary Stats				**Pre-treatment Trend**
	Mean(sd) (1)	**N (2)**	**Mean(sd) (3)**	**N (4)**	**Correlation w/ Dist. (P val.) (5)**
Age of Firms	6.053 (18.096)	58,518	1.341 (16.654)	29,259	-0.100 (0.403)
FDI invested firm	0.082 (0.274)	58,518	-0.000 (0.017)	29,259	0.000 (0.160)
SOE firm	0.126 (0.332)	58,518	-0.005 (0.084)	29,259	0.001 (0.018)
log(Total Revenue)	9.163 (2.088)	58,518	0.253 (1.249)	29,259	0.001 (0.916)
log(Assets)	9.195 (1.719)	58,518	0.110 (0.560)	29,259	0.001 (0.747)
log(Employment)	3.792 (1.291)	58,518	0.044 (0.629)	29,259	0.002 (0.610)
Number of other activities	0.180 (0.504)	58,518	0.015 (0.406)	29,259	0.002 (0.497)

Table 3: SUMMARY STATISTICS ON INFORMATION AND COMMUNICATION TECHNOLOGY VARIABLES

	Total	
Year	2004	2009
log(number of PC per worker)	0.12 (0.15)	0.15 (0.16)
log(number of PC with Internet per worker)	0.04 (0.1)	0.12 (0.16)
log(number of PC with Lan per worker)	0.04 (0.12)	0.1 (0.16)
Has Internet (1 0)	0.49 (0.5)	0.85 (0.35)
observations	34977	54614

Notes: Source: Annual Enterprise Census of Vietnam.

Table 4: FIRM FEMALE LABOR SHARE AND ICT ADOPTION (OLS), FULL SAMPLE

	(1)	**(2)**	**(3)**	**(4)**
Number of PCs with internet per worker (log)	0.059*** (0.005)			
Number of PCs with LAN per worker (log)		0.037*** (0.004)		
Number of PCs per worker (log)			0.091*** (0.005)	
log(DistanceToNode) × Post2007				-0.002** (0.001)
N	183,895	177,147	277,110	255,308
N Clusters	52,860	51,565	66,450	40,236
Adj. R^2	0.802	0.804	0.780	0.760
Regression F-Stat	143.767	133.952	251.224	157.752
# of Years	5	5	7	8
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm Level Control	Yes	Yes	Yes	Yes

Notes: Standard errors are clustered at the firm-level. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 5: FIRM FEMALE LABOR SHARE AND ICT ADOPTION (2SLS)

	(1)	(2)	(3)
Number of PCs with internet per worker (log)	0.208**		
	(0.087)		
Number of PCs with LAN per worker (log)		0.288**	
		(0.119)	
Number of PCs per worker (log)			0.336**
			(0.149)
N	158,011	155,275	154,306
N Clusters	42,629	42,456	41,763
Adj. R^2	0.017	-0.017	0.003
Regression F-Stat	107.904	101.871	110.947
Kleibergen-Paap Wald Rank F Stat	196.0	103.3	76.9
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm Level Control	Yes	Yes	Yes

Notes: All results are 2sls estimators, using $\log(DistanceToNode) * Post2007$ as the instrument. We exclude locations that are more than 20km from the nearest node. Standard errors are clustered at the firm-level. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 6: DIFFERENTIAL IMPACT OF ICT BY INDUSTRY

	(1)	(2)
Number of PCs with internet per worker (log)	0.225	0.253**
	(0.182)	(0.105)
... $\times$ Service Sector	-0.014	
	(0.091)	
... $\times$ Manufacturing Sector		0.206**
		(0.087)
N	155,248	155,248
N Clusters	41,899	41,899
Adj. R^2	0.017	-0.010
Regression F-Stat	94.785	88.946
Firm FE	Yes	Yes
Year FE	Yes	Yes
Firm Level Control	Yes	Yes

Notes: All results are 2sls estimators, All results are 2sls estimators, using $\log(DistanceToNode) * Post2007$ and $\log(Distance2Node) * Post2007 * T_j$ as instruments.. We exclude locations that are more than 20km from the nearest node. Standard errors are clustered at the firm-level. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 7: DIFFERENTIAL IMPACT OF ICT BY INDUSTRY-LEVEL TASK INTENSITY, 20KM

Panel A: Services				
	(1)	**(2)**	**(3)**	**(4)**
Number of PCs with internet per worker (log)	0.164	0.009	0.029	0.004
	(0.284)	(0.249)	(0.242)	(0.229)
... × Routine	-0.100***			
	(0.036)			
... × Social		0.107***		
		(0.037)		
... × Customer			0.116**	
			(0.045)	
... × Service				0.109**
				(0.045)
N	51,469	51,469	51,469	51,469
N Clusters	14,359	14,359	14,359	14,359
Adj. R^2	0.021	0.026	0.024	0.026
Regression F-Stat	30.225	30.465	30.652	30.508
Panel B: Manufacturing				
Number of PCs with internet per worker (log)	0.495*	0.619	0.632	0.645
	(0.291)	(0.408)	(0.389)	(0.392)
... × Routine	-0.035			
	(0.071)			
... × Social		-0.130		
		(0.126)		
... × Customer			-0.146	
			(0.110)	
... × Service				-0.158
				(0.113)
N	54,405	54,405	54,405	54,405
N Clusters	14,415	14,415	14,415	14,415
Adj. R^2	-0.055	-0.073	-0.074	-0.075
Regression F-Stat	1320.364	1370.898	1372.843	1377.732

Notes: Panel A include all service industries and Panel B includes all manufacturing industries: All results are 2sls estimators, using log(DistanceToNode)*Post2007 and log(Distance2Node)*Post2007*T_j as instruments. Independent variables: pcint/worker=log(number of PC with Internet per worker); dummy variables for manual, routine, social, customer and service task intensity equal to one if the industry-level task intensity is above median; We exclude locations that are more than 20km away from the nearest node. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. Standard errors are clustered at the firm level. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 8: HOUSEHOLD LABOR MARKET OUTCOMES AND ICT: BY GENDER

	(1) income	(2) income	(3) working	(4) working
log(DistanceToNode)*Post2007	-0.0567***	-0.0493***	-0.0100**	-0.0055
	(0.009)	(0.008)	(0.004)	(0.004)
Observations	82680	88186	149186	139767
Fixed Effects		province*year		
Other Controls	Yes	Yes	Yes	Yes
Gender	female	male	female	male

Notes: Dependent variables: "income" measures the log income in year t conditional on working. "working" is an indicator for paid employment status in year t. We exclude locations that are more than 20km away from the nearest node. All regressions include province*year fixed effects, as well as controls for the individual characteristics. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 9: HOUSEHOLD INFORMALITY AND ICT: BY GENDER

	(1) self-employed	(2) self-employed	(3) informality	(4) informality
log(DistanceToNode)*Post2007	0.0108**	0.0080	0.0116**	0.0099*
	(0.005)	(0.006)	(0.005)	(0.005)
Observations	82692	88202	82692	88202
Fixed Effects		province*year		
Other Controls	Yes	Yes	Yes	Yes
Gender	female	male	female	male

Notes: Dependent variables: "self-employed" is an indicator for whether the individual is self-employed. "informality" is an indicator for whether the individual works for a household business. We exclude locations that are more than 20km away from the nearest node. All regressions include province*year fixed effects, as well as controls for the individual characteristics. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 10: HOUSEHOLD HOURS, EXPENDITURE AND ICT

	(1) Hours	(2) Hours	(3) Expenditure
log(DistanceToNode)*Post2007	-0.0143***	0.0022	-0.2460***
	(0.004)	(0.003)	(0.023)
Observations	82653	88170	170894
Fixed Effects		province*year	
Other Controls	Yes	Yes	Yes
Gender	female	male	both

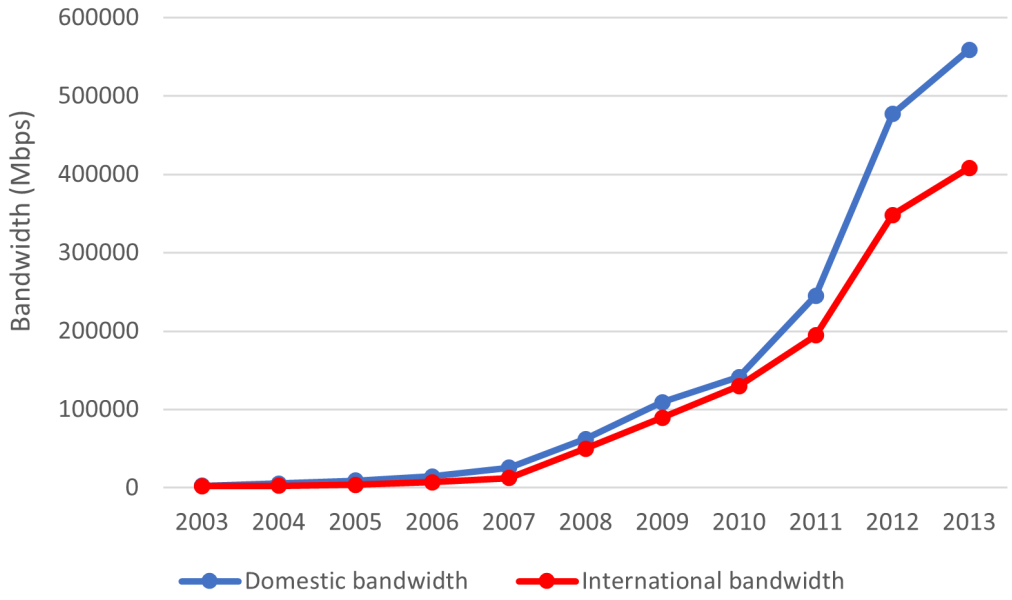
Notes: Dependent variables: "Hours" is the log of average working hours per day. "Expenditure" is the log of total household expenditure, in real terms. We exclude locations that are more than 20km away from the nearest node. All regressions include province*year fixed effects, as well as controls for the individual characteristics. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 11: HOUSEHOLD OCCUPATIONAL TASK INTENSITY

Second stage outcomes	Occupational task intensity measures								
	(1) Manual	(2) Manual	(3) Social	(4) Social	(5) Customer	(6) Customer	(7) Service	(8) Service
log(DistanceToNode)*Post2007	0.1755 ***	0.1079 ***	-0.1514 ***	0.0093	-0.1725 ***	0.0185	-0.1466 ***	-0.0206
	0.0112	0.0135	0.0268	0.026	0.0281	0.0283	0.0173	0.0182
Observations	80846	83608	80846	83608	80846	83608	80846	83608
Fixed effects	province*year							
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gender	female	male	female	male	female	male	female	male

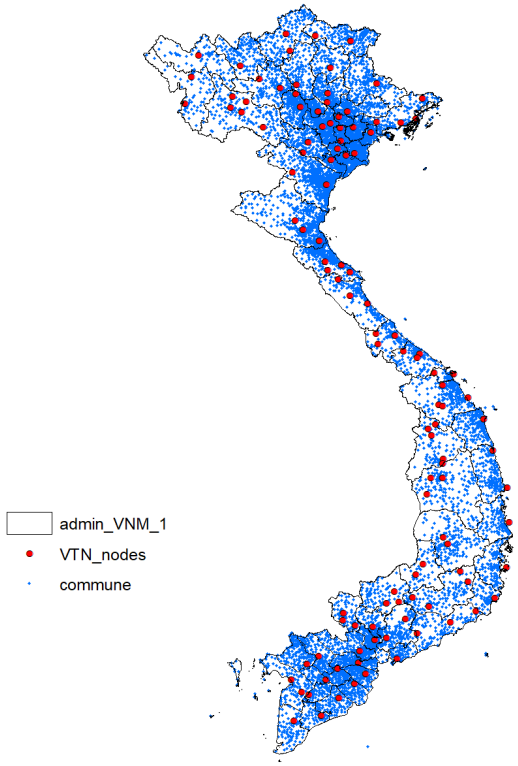
Notes: The outcome variables are occupational task intensity measures along the "manual", "social", "customer" and "service" based on concordances from the VHLSS to ONET measures in Autor et al. (2003) and Deming (2017). All regressions include province*year fixed effects, as well as controls for the individual characteristics. */**/*** denotes significant at the 10% / 5% / 1% levels.

Figure 1: Domestic and International Bandwidth



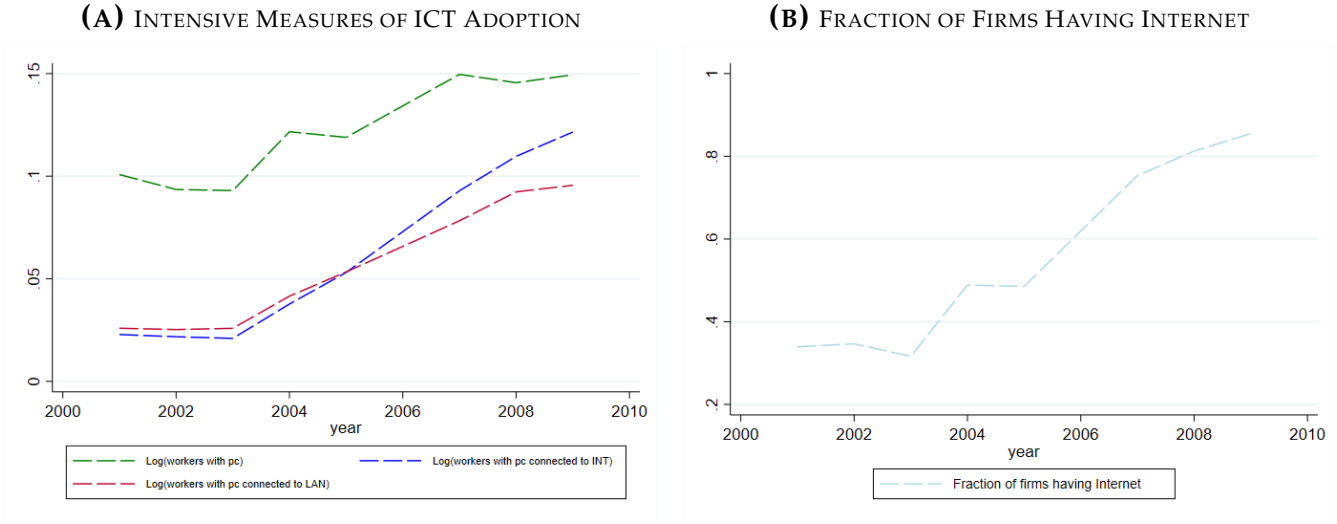
Notes: This figure plots the average domestic and international bandwidth in Vietnam from 2003 to 2013, according to data from the Vietnam Internet Network Information Center (VNNIC, 2013).

Figure 2: Main Terrestrial Backbone Node Sites and Vietnamese Communes



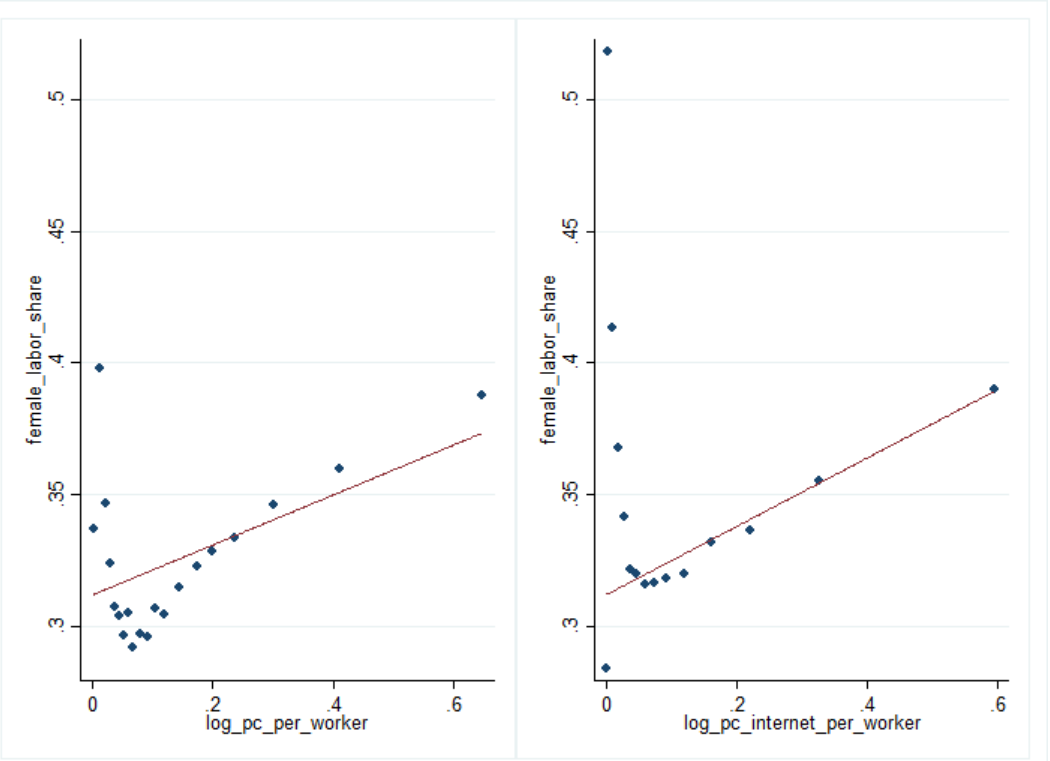
Notes: This map shows the main backbone node sites *(in red)* in Vietnam and the centroids of Vietnamese communes *(in blue)*. The backbone and node sites map is digitized using the ITU original transmission network maps. Boundaries show Vietnamese administrative level one divisions.

Figure 3: Firm ICT Adoption



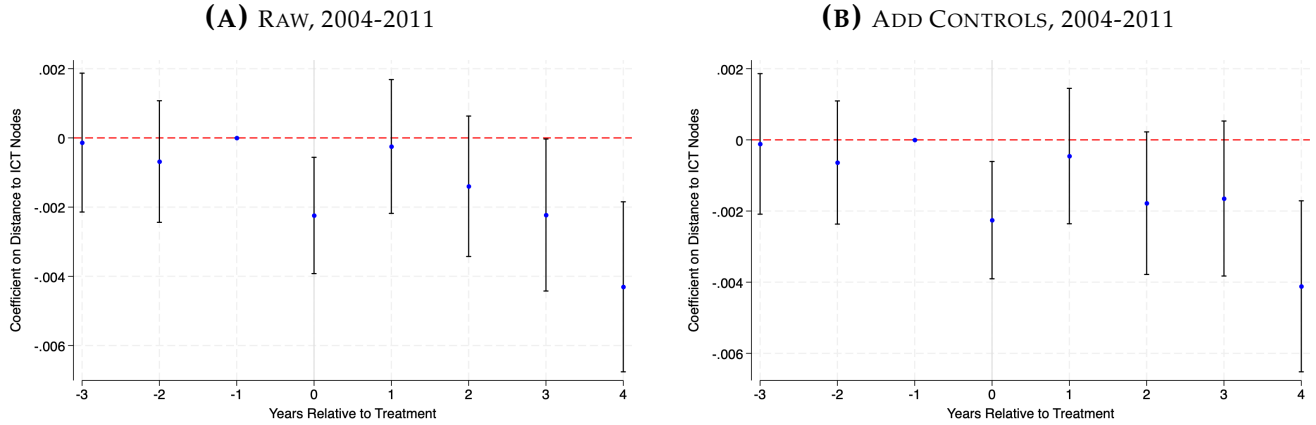
Notes:

Figure 4: Female Labor Share and Firm ICT Adoption



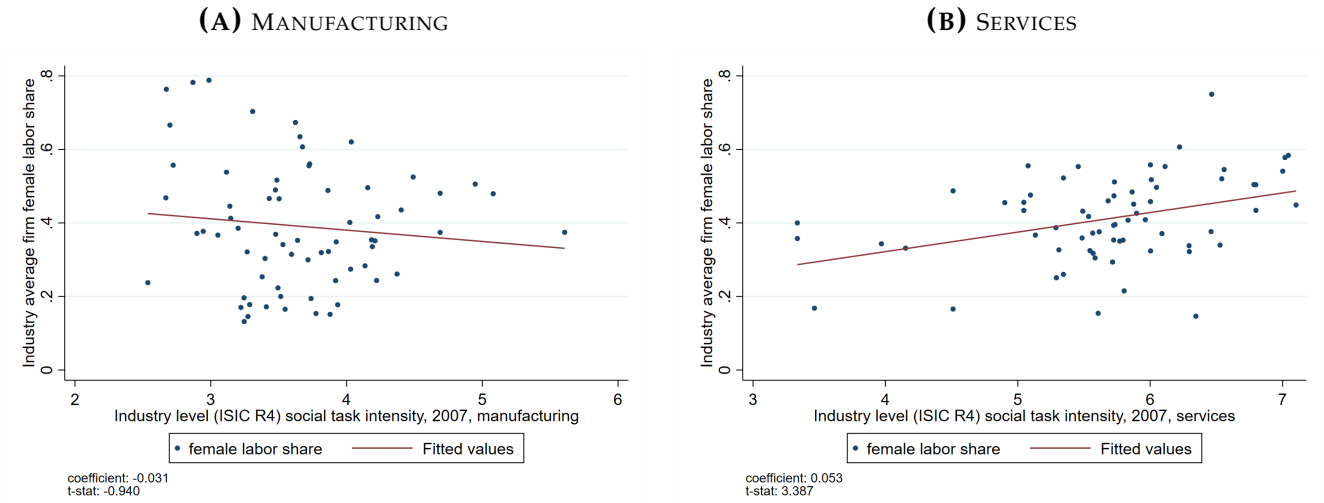
Notes:

Figure 5: Pretrend Analysis, Female Labor Share



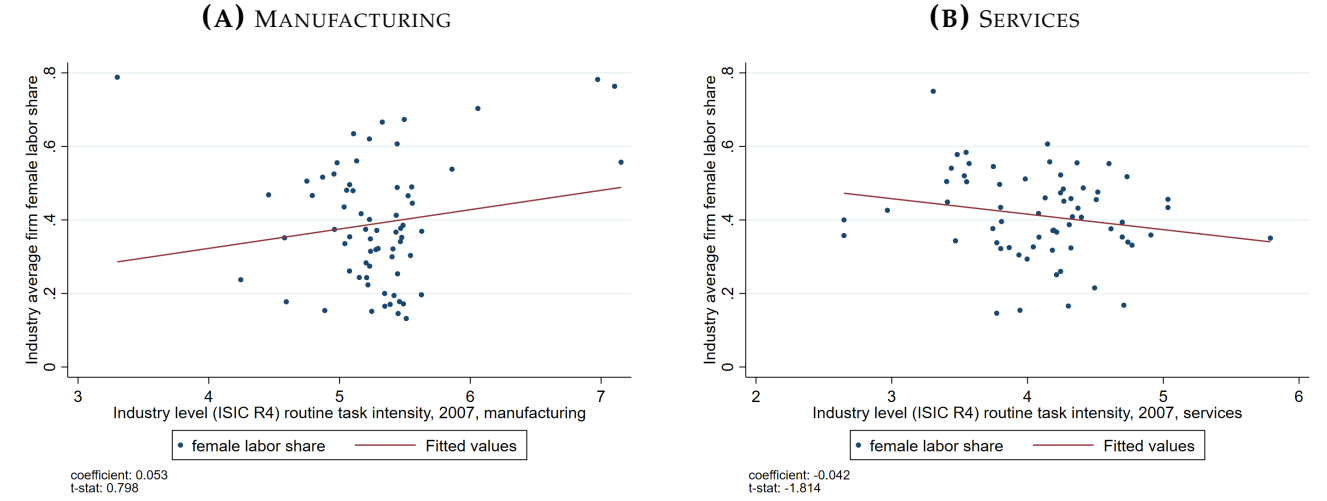
Notes:

Figure 6: Gender Sorting by Social Task Intensity in the Raw Data



Notes: This figure plots industry (ISIC Rev4) level raw correlations between female employment share and social task intensity using the Vietnam Enterprise Surveys in 2007. The left panel plots the correlation for manufacturing sectors, while the right panel plots the correlation for service sectors.

Figure 7: Gender Sorting by Routine Task Intensity in the Raw Data



Notes: This figure plots industry (ISIC Rev4) level raw correlations between female employment share and routine task intensity using the Vietnam Enterprise Surveys in 2007. The left panel plots the correlation for manufacturing sectors, while the right panel plots the correlation for service sectors.

A Appendix Tables and Figures

Table A.1: QUALITY OF BROADBAND INTERNET ACROSS SELECT COUNTRIES

Country	Speed (bits per second per Internet user)	Affordability ($ per month)
PRC	6,530	19
Indonesia	6,584	29
Cambodia	17,792	12
Viet Nam	24,374	3
Malaysia	34,119	10
Philippines	37,409	22
Thailand	64,907	19
United States	99,147	16

Notes: Source: World Bank. World Development Indicators.

Table A.2: VIETNAM LABOR FORCE STATISTICS BY GENDER

	2007		2013	
	Male	**Female**	**Male**	**Female**
Labor force participation rate	81.4	75.1	84.6	76.9
Employment status of those in labor force				
Unemployed	2.2	2	1.5	1.2
Employer	3.8	2.8	3.4	1.5
Own-account	46.2	56.5	42.8	45.1
Unpaid/Other	12.2	14.1	12	22.5
Wage	35.7	24.6	40.4	29.8
Education of those in labor force				
Primary	41.1	47.1	35.5	41.3
Some secondary	29.8	28.9	30.8	31.5
Secondary	13.4	11.2	17.9	12.8
Secondary tech	8.6	6.5	6.7	5
College	7.1	6.4	9.1	9.5

Notes: Statistics based on individuals ages 15–65; Percent values shown. Source: Vietnam Labor Force Surveys.

Table A.3: VIETNAM MONTHLY WAGES FOR WAGE WORKERS BY GENDER AND EDUCATION ($)

	2007			2013		
	Male	**Female**	**Ratio**	**Male**	**Female**	**Ratio**
Primary	1,057	769	1.37	2,974	2,314	1.29
Some secondary	1,044	754	1.38	3,225	2,791	1.16
Secondary	1,249	1,055	1.18	3,774	3,189	1.18
Secondary tech	1,648	1,406	1.17	4,119	3,567	1.15
College	2,537	2,085	1.22	5,815	4,751	1.22

Notes: Statistics based on individuals ages 15–65; Percent values shown.
Source: Vietnam Labor Force Surveys.

Table A.4: FIRST STAGE

	# PCs w/ internet per worker (log)	# PCs w/ LAN per worker (log)	# PCs per worker (log)
	(1)	(2)	(3)
log(DistanceToNode) × Post2007	-0.010***	-0.008***	-0.006***
	(0.001)	(0.001)	(0.001)
N	160,963	158,177	156,083
N Clusters	43,317	43,164	42,132
Adj. R^2	0.687	0.667	0.746
Regression F-Stat	359.588	170.449	1127.895
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm Level Control	Yes	Yes	Yes

Notes:

Table A.5: FIRM FEMALE LABOR SHARE AND ICT ADOPTION (OLS), 20 KM

	(1)	(2)	(3)	(4)
Number of PCs with internet per worker (log)	0.060***			
	(0.005)			
Number of PCs with LAN per worker (log)		0.038***		
		(0.004)		
Number of PCs per worker (log)			0.105***	
			(0.006)	
log(DistanceToNode) × Post2007				-0.001
				(0.001)
N	180,791	176,515	177,493	164,739
N Clusters	52,248	51,438	51,597	39,327
Adj. R^2	0.806	0.806	0.805	0.776
Regression F-Stat	141.932	133.960	155.528	105.168
# of Years	5	5	5	5
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm Level Control	Yes	Yes	Yes	Yes

Notes: We exclude locations that are more than 20km from the nearest node. Standard errors are clustered at the firm-level. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table A.6: ICT AND FEMALE LABOR DEMAND, 2SLS, ADDITIONAL CONTROLS AND FIXED EFFECTS

	Baseline			+ Control Urbanization			+ Control Population Growth			+ Control Globalization		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Number of PCs with internet per worker (log)	0.208**			0.250***			0.247***			0.406*		
	(0.087)			(0.096)			(0.096)			(0.221)		
Number of PCs with LAN per worker (log)		0.288**			0.349***			0.343***			0.566*	
		(0.119)			(0.134)			(0.133)			(0.318)	
Number of PCs per worker (log)			0.336**			0.416**			0.410**			0.676
			(0.149)			(0.166)			(0.165)			(0.423)
N	158,011	155,275	154,306	158,011	155,275	154,306	158,008	155,272	154,303	157,988	155,252	154,285
N Clusters	42,629	42,456	41,763	42,629	42,456	41,763	42,629	42,456	41,763	42,619	42,446	41,754
Adj. R^2	0.017	-0.017	0.003	0.008	-0.041	-0.024	0.009	-0.038	-0.022	-0.043	-0.173	-0.168
Regression F-Stat	107.904	101.871	110.947	69.822	65.047	71.302	65.714	61.302	67.001	64.186	56.632	61.791
Distance to CBD × Year				Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Population							Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year										Yes	Yes	Yes

Table A.7: ICT AND FEMALE LABOR DEMAND, 2SLS, VARYING LOCATION RESTRICTIONS

	Radius: 15 km			Radius: 20 km			Radius: 25 km		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Number of PCs with internet per worker (log)	0.289**			0.208**			0.147**		
	(0.112)			(0.087)			(0.072)		
Number of PCs with LAN per worker (log)		0.428**			0.288**			0.205**	
		(0.172)			(0.119)			(0.099)	
Number of PCs per worker (log)			0.424**			0.336**			0.263**
			(0.182)			(0.149)			(0.132)
N	138,726	136,368	136,186	158,011	155,275	154,306	166,949	164,021	162,364
N Clusters	37,614	37,470	36,992	42,629	42,456	41,763	44,996	44,811	43,936
Adj. R^2	-0.004	-0.088	-0.032	0.017	-0.017	0.003	0.025	0.009	0.020
Regression F-Stat	96.192	87.308	98.865	107.904	101.871	110.947	109.522	104.489	113.750
Kleibergen-Paap Wald Rank F Stat	116.3	51.1	51.8	196.0	103.3	76.9	293.3	150.4	98.6
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Level Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All results are 2sls estimators, using $\log(DistanceToNode) * Post2007$ as the instrument. We exclude locations that are more than 20km from the nearest node. Standard errors are clustered at the firm-level. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table A.8: FIRM FEMALE LABOR SHARE AND ICT ADOPTION (2SLS, TWO-WAY CLUSTERING)

	(1)	(2)	(3)
Number of PCs with internet per worker (log)	0.208**		
	(0.091)		
Number of PCs with LAN per worker (log)		0.288**	
		(0.125)	
Number of PCs per worker (log)			0.336**
			(0.152)
N	158,011	155,275	154,306
N Clusters	14,822	14,624	14,158
Adj. R^2	0.017	-0.017	0.003
Regression F-Stat	99.745	93.877	102.704
Kleibergen-Paap Wald Rank F Stat	126.3	80.1	65.9

Notes: All results are 2sls estimators, using log(DistanceToNode)*Post2007 as the instrument. Independent variables: pc/worker=log(number of PC per worker), pcint/worker=log(number of PC with Internet per worker), pclan/worker=log(number of PC with Lan per worker); Standard errors are clustered at the firm, and commune-by-year level. We exclude locations that are more than 20km from the nearest node. All regressions include year and firm fixed effects, as well as a vector of firm-level covariates. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table A.9: SECTORS BY SOCIAL TASK INTENSITY

Highest Sectors	Lowest Sectors
Food Services	Sawmilling and Planing of Wood
Retail Services	Wood Product Manufacturing
Motion Picture, Video and TV activities	Manufacture of Articles of Fur
Facilities Support	Leather Tanning and Manufacturing
Management Consulting Services	Manufacturing of Rubber

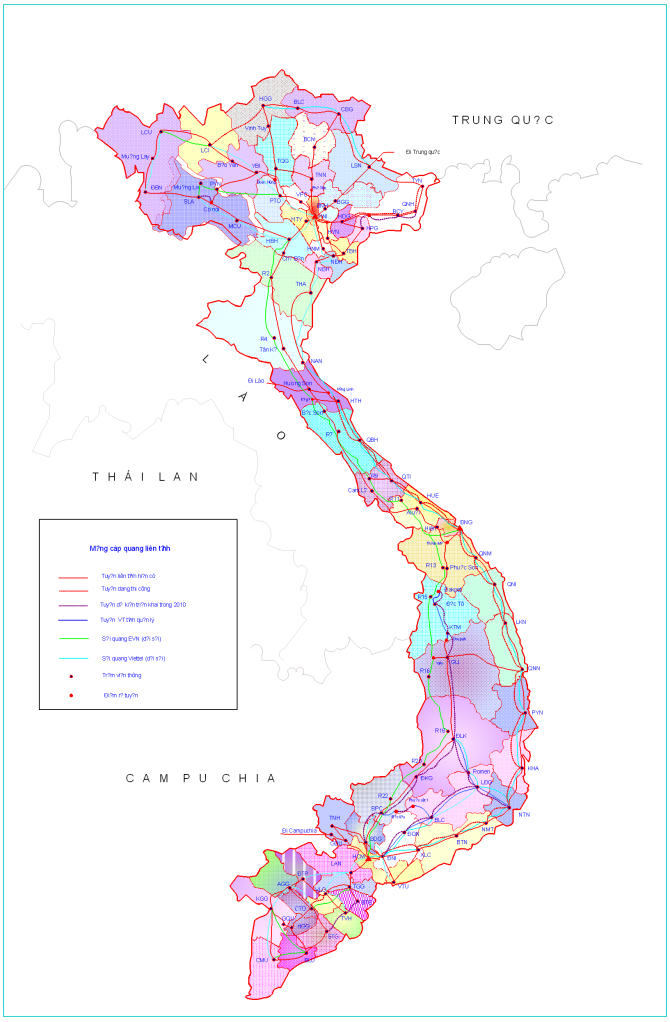
Notes:

Table A.10: GENDER SORTING BY SOCIAL TASK INTENSITY

Dependent variable	Firm female labor share					
	(1)		(2)		(3)	
Social Task Intensity	0.026	***	0.026	***	0.022	***
	0.001		0.001		0.001	
Observations	310317		310317		310317	
Firm-level Controls	Y		Y		Y	
Year FE			Y		Y	
Province FE					Y	
Clustering			Firm			

Notes: Independent variable: industry-level measure of social task intensity (Deming, 2017). Dependent variable: firm-level female labor share. Standard errors are clustered at the firm-level. Significant at *** 1%, ** 5%, * 10%.

Figure A.1: Map of Domestic Terrestrial Backbone in Vietnam



Notes: This map shows the main terrestrial backbone and node sites in Vietnam, according to the ITU Trasnsmission Network Data and the Vietnam Telecom National (VTN). The backbone network consists of fiber optic transmission systems connecting Hanoi to Ho Chi Minh City, as well as regional networks in the North, Northeast, Central regions and the South.