Do Investments in Digital Infrastructure Advance Gender Parity? Evidence from Türkiye *

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Abstract

This paper examines the effects of infrastructure investments on female labor market outcomes in Türkiye. Utilizing the spatial and temporal variation in fiber optic rollout during the 2010s and employing comprehensive administrative linked employer-employee data, we find that high-speed Internet access leads to an increase in relative female employment and wages, thereby reducing gender disparities in labor markets. The primary driver behind this positive impact on women is the expansion of work-from-home opportunities resulting from improved Internet connectivity. However, we observe variations in labor market outcomes between low- and high-skill women. Our findings are robust to various sensitivity checks, including alternative data sources constructed from labor force surveys. In particular, these unambiguous effects on female employment opportunities are not evident from large-scale investments in road infrastructure. Our results underscore the significance of digital infrastructure in advancing gender equality and provide valuable insights for policymakers seeking to foster inclusive economic growth.

Keywords: digital infrastructure, gender equality, labor markets, high-speed Internet, work-from-home *JEL Codes:* J16, J82, L96, O14, O33

*The views expressed in this paper are solely those of the author and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent.

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1 Introduction

Digital infrastructure plays a pivotal role in driving economic growth, creating jobs, and lifting populations out of poverty. It serves as a catalyst for economic development. For households and individuals, digital technology improves access to timely information and reduces transaction costs, increases educational outcomes, participation in the labor force, income, consumption, and welfare (Jensen, 2007; Aker and Mbiti, 2010; Hjort and Poulsen, 2019a; Bahia et al., 2023; Viollaz and Winkler, 2022; Derksen et al., 2022). In principle, digital infrastructure should particularly boost female participation in economic activity through, for example, expansion in flexible and remote job opportunities. Yet there are not many studies that have systematically explored the benefits of investments in electronic infrastructure for women, especially in comparison with other forms of infrastructure investments such as roads, highways, or ports.

This paper aims to fill this gap by examining the impact of investments in digital infrastructure on gender equality in labor markets. Using spatial and temporal variation in fiber optic rollout in Türkiye during the 2010s and combining this information with rich administrative linked employer-employee data, we show that the high-speed Internet increases relative female employment and wages, thus narrowing the gender gap in labor markets. The administrative data on firms and workers also report detailed occupation information which we use to investigate heterogeneous effects of high-speed Internet on relative female labor market outcomes across occupations. We find that our baseline results are driven by teleworkable occupations, suggesting the rise in work-from-home opportunities with the high-speed Internet as an important channel.

We conduct several robustness checks to test the sensitivity of our baseline results. First, we include an interaction term between the fiber network and the intensity of female employment to address the potential selection of greater females in teleworkable occupations. The estimated coefficient on the interaction with teleworkability remains unchanged, suggesting that the relative increase in female employment or wages is driven

by their participation in teleworkable occupations. Second, we replace region-occupation fixed effects with region-industry-occupation fixed effects to exploit variation within our cross-section unit over time. The estimated effects of improvements in digital connectivity on relative female employment and earnings in teleworkable occupations remain robust to the addition of more disaggregated fixed effects. Third, we examine the role of skill intensity by including an interaction term between the fiber network and an indicator of skill intensity. The results confirm that the employment effects of the high-speed Internet on females in teleworkable occupations are robust to the selection of women by skills.

Considering the transmission mechanisms underlying the impact of digital connectivity we find that high-speed Internet availability, encourages women to switch occupations within a province, particularly from non-teleworkable to teleworkable jobs. The effect on labor market outcomes for females are more pronounced when the move is between two teleworkable occupations compared to a move from a non-teleworkable occupation, suggesting a common set of skills required for teleworkable jobs. Additionally, the impact of Internet connectivity on women's job mobility differs based on the skill intensity of the initial occupation. Women in low-skill occupations are more likely to transition to teleworkable jobs with improved Internet connectivity, while women in high-skill occupations benefit from Internet connectivity only when the move is between two teleworkable occupations. Thus, women in high-skill occupations also experience relative wage gains due to enhanced digital connectivity.

Lastly, we compare the effects of digital infrastructure investments with investments in road infrastructure in reducing gender disparities. We exploit the large-scale public investment in roads in Türkiye during the 2000s, which aimed to improve safety and travel times across the country Cosar et al. (2021). Our findings suggest that unlike the effect of digital infrastructure, the impact of road infrastructure investments on female labor market outcomes is not unambiguous. While improvements in *market access* are

associated with an increase in female employment share, shorter commute times to the most populated district, and *competition effects* from proximate districts reduce female employment share.

We contribute to the vast and growing literature investigating the effects of Internet access on various economic outcomes Hjort and Tian (2021). These include employment creation Hjort and Poulsen (2019a), skill composition of employment Akerman et al. (2015), and household earnings Zuo (2021). For businesses, digital technology can improve decision making, increase efficiency, facilitate innovation, and expand markets Bloom et al. (2012); Barrero et al. (2023); Demir et al. (2023). Firms connected to the Internet are also more likely to provide on-the-job training, contributing to the upskilling of workers. Investment in digital infrastructure can also foster a country's integration into regional and global value chains Freund and Weinhold (2004) and facilitates export diversification as well as access to foreign inputs Fernandes et al. (2019); Malgouyres et al. (2021); Hjort and Poulsen (2019b).

Our findings have important implications for policymakers aiming to foster gender equality by leveraging digital infrastructure as a tool for inclusive economic development. Our research suggests that to harness the full potential of digital connectivity for inclusive economic growth, policymakers could prioritize facilitating flexible work-from-home arrangements through transforming social norms, updating legal regulations, and strengthening digital data protection and cyber security. In addition, making complementary investments in skills, mentoring, and training to close the digital gap for women are also crucial. Finally, implementing policies, reforms, and interventions would be critical to enable women to switch to teleworkable occupations by reducing barriers, addressing occupational segregation, and enhancing access to information and resources.

The remainder of the paper proceeds as follows. Section 2 describes the data sources and the background of fibre cable rollout in Turkey. Section 3 sets up the empirical strategy while Section 4 presents the results for the effects of fibre cable rollout on relative

female employment outcomes. Section 5 concludes.

2 Data

Our analysis combines spatially disaggregated data on the investment in fibre cable with two micro-level datasets from Türkiye.

2.1 Micro-level data on employment and wages

For most of our analysis, we use linked employer-employee data, an administrative dataset collected by the Social Security Institution. It covers the universe of formal workers and allows tracking workers over time and across establishments (plants) over the 2012-2019 period. It reports (monthly) wage, age, gender, and occupation of every worker employed by any establishment in Türkiye.[1] Establishments can further be linked to firms using unique social security identifiers. This dataset is merged using unique identifiers with administrative establishment registry, which reports their location (province and district) and the main industry of operation (4-digit NACE ("Nomenclature statistique des Activites economiques dans la Communaute Europeenne") code).

We also deploy the labor Force Survey, which is a micro-level data comprising repeated cross-section of households. It reports information on the structure of the labor force, including employment status, as well as hours worked, salary, and broadly-defined occupation and industry for employed individuals.[2] Importantly, for our purposes, it also reports the intensity of work-from-home (WFH).

Using these multiple micro-level datasets, we explore gendered differences in labor market participation, wages, and transitions from regular to remote jobs by exploiting

[1] Occupation information at the 4-digit International Standard Classification of Occupations (ISCO) level is available from 2014 onwards.

[2] More details about the survey can be found here: https://data.tuik.gov.tr/Kategori/GetKategori?p=Employment,-Unemployment-and-Wages-108.

the spatial variation in fibre cable Internet infrastructure across Turkish regions. This brings us to the complementary database used in our paper.

2.2 Regional data on Internet infrastructure investment

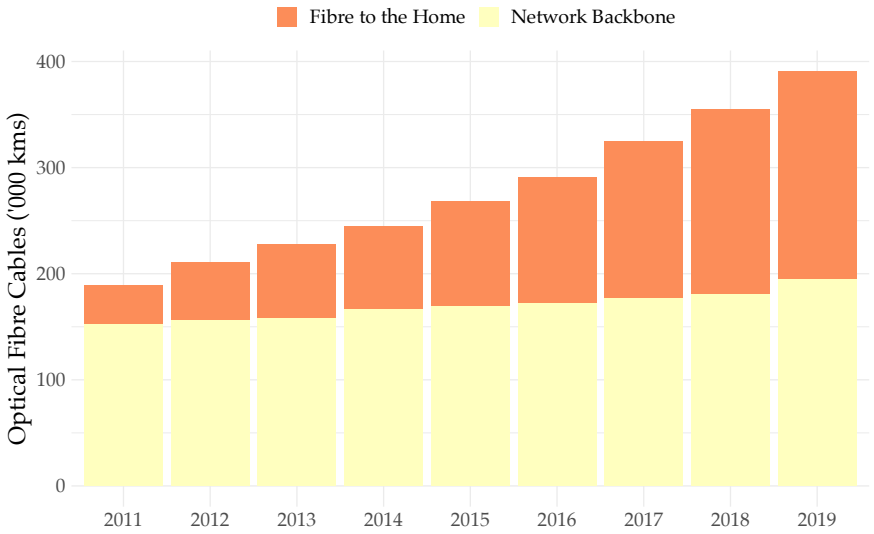
Prior to 2010, Türkiye's Internet infrastructure was extensive but had limited speed. In October 2011, the government made a significant decision regarding Fibre Access Services, stipulating their exemption from regulations for a span of five years or until the proportion of fiber Internet subscribers reached 25% of the fixed broadband subscriber base. Over the subsequent eight years, from 2011 to 2019, the fiber network expanded extensively, covering a remarkable distance of 390.8 thousand kilometers, equivalent to an impressive 0.48 kilometers per square kilometer of land area.

In addition, the private Internet providers were granted the authority to utilize Botas, the local natural gas and oil distributor's fiber cables, which played a pivotal role in accelerating the rollout of fiber connectivity across the country. Figure 1 shows that the length of optical fibre cables rolled out in Türkiye almost doubled from 2012 to 2019. It also shows that investment in fibre optic infrastructure was primarily directed towards rolling out "fiber to the home" for farther locations and less towards the "network backbone".[3] We exploit distance from urban centers to Botas pipeline network as a source of exogenous variation to construct our instrument in the empirical analysis. Between 2012 and 2019, not only has the number of subscribers (both households and firms) to fiber Internet lines increased five-fold, but their share in all fixed broadband connections has also been steadily rising. As of 2020, the fibre Internet lines accounted for 23.9% of all fixed broadband connections in Türkiye, converging to the OECD average of 30.6%.

We obtain data on rollout of fibre Internet from Information and Communication Technologies Authority (ICTA) in Turkey. This provides us the length of fibre optic cables laid

[3]Backbone infrastructure refers to the primary network connections forming the foundation of the network while FTTH refers to the installation of fiber-optic cables directly to individual buildings.

Figure 1: **Fibre Internet Rollout**



Note: The top panel depicts the evolution of the number of fibre Internet subscribers in Türkiye during the period 2012-2019. The bottom panel shows the breakdown of fixed broadband connections into fibre, xDSL, Cable TV and others. Over 2012-2019, not only did the number of subscribers increase five-fold, but the share of broadband subscriptions due to fibre Internet also increased.

out in each province across years 2012-2019. Fiber optic cables intensity across regions indeed translates to better Internet connectivity in Turkish provinces, as measured by upload and download speeds reported across provinces for years 2016-2019 as illustrated in Appendix Figure A1.

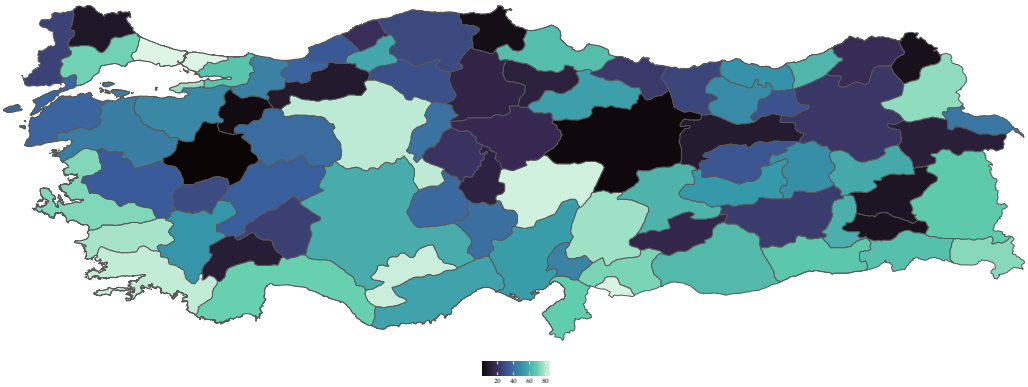
3 Empirical Strategy

We estimate the impact of digital connectivity on outcomes for women by exploiting the spatial and time variation in the roll-out of fibre optic infrastructure across Turkish provinces and years. To this end, we construct a measure of fiber intensity for each province and year. In particular, following Demir et al. (2023), we measure fiber intensity as the length of fibre optic cables rolled out in a province normalized by its land area. Formally, for a province r in year t, fibre intensity Fibre_{rt} is calculated as:

$$\text{Fibre}_{rt} = \ln\left(1 + \frac{L_{rt}}{A_r}\right), \tag{1}$$

where L_{rt} denotes the length of optical fibre cables (in kms) rolled out in province r in year t and A_r is the surface area of the province (in km^2). Figure 2 depicts the change in fibre intensity across Turkish provinces between 2012 and 2019.

Figure 2: **Change in Optical Fibre Length**



Note: This figure depicts the spatial variation in optical fibre cable roll-out across Turkish provinces during the period 2012-2019. The median Turkish province saw a 68% increase in optical fibre roll-out, with a maximum of 177% for Istanbul and a minimum of 31% for Kutahya.

To investigate the effect of improved Internet connectivity on labor market outcomes, particularly for women, we use the administrative linked employer-employee dataset which covers the universe of private sector formal workers. This data provides the location of workplaces, allowing us to exploit the differential change in fibre cable availability across Turkish provinces. Moreover, the detailed occupation information reported in the data allows us to study the possibility of heterogeneous effects across occupations, particularly between teleworkable and non-teleworkable occupations, and thus explore WFH as a channel through which high-speed Internet affects female labor market outcomes.

We aggregate employment (or earnings) at the level of provinces (i.e. NUTS3 regions), 4-digit NACE industries, occupations (4-digit ISCO codes) and gender to study whether improvements in fibre connectivity in a province is associated with higher female employment or earnings. We estimate two specifications. The first one uses gender-specific outcome variables and ignores heterogenous effects across occupations:

$$\text{Outcome}_{rosgt} = \beta \text{Female}_g * \text{Fibre}_{rt} + \alpha_{sot} + \alpha^g_{ot} + \alpha_{rs} + \alpha_{rt} + \epsilon_{rosgt}, \tag{2}$$

The specification is saturated with a rich set of fixed effects. We use time-varying provincial fixed effects (α_{rt}) to control for any demand and supply related shocks affecting the local labor market. In addition, with α_{sot}, we account for potential labor supply changes at the level of industries and occupations. α^g_{ot} further account for gender-related compositional changes at the level of occupations. Finally, α_{rs} control for the industry composition in provinces. Our second specification aims to study the potentially heterogenous effects of improvements in Internet connectivity across occupations. To do so, we use as dependent variable, relative female outcomes, e.g. share of female employment or relative female earnings:

$$\text{Relative female outcome}_{rost} = \gamma \text{Teleworkability}_o * \text{Fibre}_{rt} + \alpha_{sot} + \alpha_{rs} + \alpha_{rt} + \varepsilon_{rost} \tag{3}$$

As before, the specification is saturated with a rich set of fixed effects. We measure teleworkability of occupations based on the classification proposed by Dingel and Neiman (2020a). The coefficient of interest is γ which captures the differential effect for teleworkable occupations, which would be informative about the importance of WFH as a plausible channel.

In general, estimating the effects of improvements in infrastructure, such as roads or communication network, on key economic outcomes is challenging since allocation of investment may not be random and might be correlated with other observed or unob-

served location-specific factors. The initial phase of Türkiye's fibre Internet roll-out was concentrated in "urban and economically attractive" areas but then expanded to universal coverage. Thus, in our setting, one potential concern is that expansion of the fibre optic network is endogenous, which may create spurious correlation between increases in fibre intensity and regional outcomes. To address this concern, following the approach in Demir et al. (2023), we construct an instrument for fibre intensity for each province by exploiting the fact that the roll-out of fibre cable Internet in Türkiye kicked off after private Internet providers were granted access to use fibre cables fed through the existing gas pipes. The BOTAS optical fiber network was built decades before the start of the optical fiber network expansion. Since the BOTAS network was not designed to facilitate Internet connectivity across provinces, we can exploit plausibly exogenous variation in the distance of individual districts in Turkey to the BOTAS network to construct our instrument for Internet connectivity.

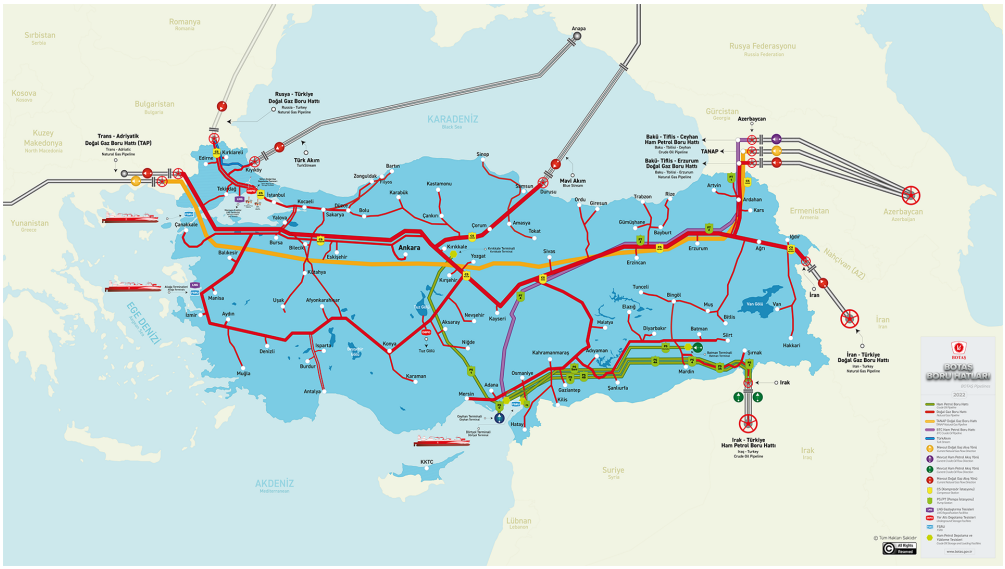
Figure 3 shows the BOTAS pipeline network. We calculate the minimum distance from each district center to the network and then aggregate distances to the province level by weighting districts with their respective population in 2011. This measure is an informative instrument for the amount of investment a region received during this period as it is negatively correlated with the cost of investing in FTTH (Fibre to the Home) network.[4] In Figure A2, we show that these distance measures across provinces are not correlated with a series of initial province characteristics, such as GDP, area, population, manufacturing share of GDP, urbanization rate, and employment rate, pertaining to the year 2011.

The informativeness of the instrument can be confirmed by running the following first stage regression equation:

$$Fibre_{r,t} = \sum_{l=2013}^{2019} \beta^l \mathbb{1}_{t=l} \times IV_r + \alpha_r + \alpha_{NUTS2,t} + e_{rt} \tag{4}$$

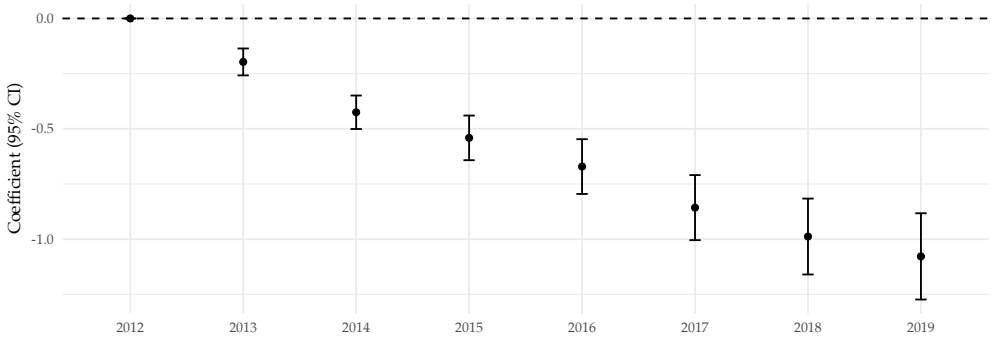
[4] As presented in Figure 1, investment in fibre network was geared towards FTTH rather than backbone investment during this period.

Figure 3: BOTAS Oil and Gas Pipeline Network



Note: This map shows the gas pipeline network of BOTAS as of the year 2011.

Figure 4: First-stage estimates



Note: The distance of a province to BOTAS pipelines is constructed as the weighted average of the distances of districts within the province where the district population are used as weights. This figure plots the coefficient estimates and the corresponding 95% confidence intervals obtained from regressing this distance on initial provincial characteristics (pertaining to 2011), controlling for NUTS2 level fixed effects.

Figure 4 presents the estimates of β^l with their 95% confidence interval. In line with our expectations, the estimated coefficients are negative and their magnitudes increase towards the end of the investment period.

4 Results

In this section we start with descriptive analysis of the gender differences in labor markets followed by a causal analysis of the impact of digital infrastructure investments on female labor market outcomes. Finally, we present the main transmission mechanism through which the impact is mediated.

4.1 Gender differences in labor markets: Descriptive analysis

As a first pass of the data, we investigate the extent of gender gap in employment and wages in Türkiye using the Household labor Force Survey data. First column of Table 1 shows that women are less likely to be employed for a given region (NUTS2 level) and year, and conditional on various individual characteristics such as age, experience, education level, and marital status. The gap is also visible in wages earned per hour of work for employed women.

The Household labor Force Survey comprises information on individuals' ability to WFH and their intensity or frequency. Figures A3 and A4 show the fraction of survey respondents who work-from-home at least part of the time. Both figures show significant variation in WFH intensity across industries or occupations. Also, women are more likely to WFH than men. This final observation is also confirmed by descriptive regression analysis (Table 1, column 3) that controls for unobserved time-varying regional, industry, and occupation level factors. We will exploit this pattern further, and study how it responds to the availability of high-speed Internet in the next section.

High-speed Internet availability affects female labor market outcomes through both the demand and the supply channels. On the demand side, digital connectivity increases firm productivity and employment opportunities particularly in occupations with greater amenability for remote work, that is, more teleworkable occupations. On the supply side, due to childcare responsibilities, women may be more likely to take up such jobs espe-

Table 1: Gender Differences in Employment, Wages, and WFH Intensity

Dependent Variable:	Employed (1)	(Log) Wage per hour (2)	WFH (3)
Female	-0.296***	-0.0869***	0.0339**
	(0.00743)	(0.00648)	(0.0135)
Age	0.0302***	0.0429***	0.000612***
	(0.000668)	(0.00171)	(0.000131)
Age squared	-0.000368***	-0.000479***	-0.00000525***
	(0.00000895)	(0.0000216)	(0.00000145)
High school diploma	0.102***	0.136***	-0.00127
	(0.00766)	(0.00578)	(0.00141)
Married	0.0441***	0.0559***	0.00532***
	(0.0114)	(0.00329)	(0.00164)
Large employer		0.102***	-0.0120***
		(0.00421)	(0.00152)
Employed in public sector		0.427***	0.00420
		(0.0292)	(0.00263)
Has managerial responsibilities		0.165***	0.00309*
		(0.00721)	(0.00154)
Fixed Effects:			
Region×Time	✓	✓	✓
Industry×Occupation×Time		✓	✓
Region×Industry		✓	✓
Observations	3,813,289	839,758	839,758

cially if enhanced flexibility in working arrangements come at the cost of lower wages (Barrero et al. (2023)). Women may be more likely to trade off the former against the latter.

4.2 Baseline Results

To investigate the effect of improved Internet connectivity on labor market outcomes, particularly for women, we use the administrative linked employer-employee dataset which covers the universe of private sector formal workers. This data provides the location of

workplaces, allowing us to exploit the differential change in fibre cable availability across Turkish provinces. Moreover, the detailed occupation information reported in the data allows us to study the possibility of heterogeneous effects across occupations, particularly between teleworkable and non-teleworkable occupations, and thus explore WFH as a channel through which high-speed Internet affects female labor market outcomes. These results are confirmed using the Household labor Force survey data which reports directly the frequency with which individuals work-from-home.

The results obtained from estimating equation (2) for employment are presented in Appendix Table A1. While the estimated coefficient on the interaction between the female dummy and province-level fibre intensity is positive, it is imprecisely estimated for the full sample which pools all occupations. Last two columns further split the sample by teleworkability of occupations. Column 5 shows that female employment increased disproportionately in teleworkable occupations with the availability of high-speed Internet. This motivates us to move directly to our second empirical specification (3) which investigates occupation heterogeneity.

Results are presented in Table 2. First two columns estimate the effect of improvements in Internet connectivity on the fraction of female employment in a given province-industry-occupation cell at time t, and the last two columns the effect on relative female monthly wages within the same cell. The results obtained for relative female employment confirm that the availability of high-speed Internet increases the share of female employment in teleworkable occupations. This is consistent with the hypothesis that high-speed Internet makes it more feasible and efficient to WFH, thus boosting relative female employment in WFH compatible occupations. The availability of high-speed Internet also led to an increase in relative female earnings as presented in the last two columns of Table 2. While the estimated coefficient for fibre is small, and statistically insignificant (column 3), the coefficient on its interaction with occupation-level teleworkability is positive, sizeable, and statistically significant in both specifications.

Table 2: Female labor Market Outcomes and High-Speed Internet: Baseline

Dependent Variable:	Share of female employment		Relative female earnings	
	2SLS	2SLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
Fibre	-0.114		0.0133	
	(0.0768)		(0.0524)	
Teleworkability×Fibre	0.0152***	0.0153***	0.0500***	0.0501***
	(0.00198)	(0.00198)	(0.00673)	(0.00673)
Fixed Effects:				
Industry×Occupation×Time	✓	✓	✓	✓
Region×Industry	✓	✓	✓	✓
Region×Time		✓		✓
Observations	3,490,367	3,490,367	3,490,367	3,490,367

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

4.3 Robustness Checks

We test the robustness of the baseline results to several alternative specifications.

First, it possible that the increased employment in teleworkable occupation is driven by the selection of greater females in those occupations. To address this, we add to our base specification an interaction of fibre network with the intensity of female employment (Table A2, column 1).[5] Adding an interaction between Fibre_{rt} and female intensity of occupations does not change the estimated coefficient on the interaction with teleworkability, thereby suggesting that the relative increase in female employment or wages is indeed driven by their participation in teleworkable occupations.

Second, to test the robustness of our results to an alternative source of variation, we replace region-occupation fixed effects in the baseline specification with region-industry-occupation fixed effects, allowing us to exploit variation within our cross-section unit over time. The estimated effects of improvements in digital connectivity on relative female employment and earnings in teleworkable occupations are robust to the addition of more disaggregated fixed effects (Table A2, column 2).

[5]Female intensity is measured by the share of female employment in each occupation in EU 15 countries using EUROSTAT data.

Third, we suspect that the increased employment in teleworkable occupation may be attributed to the self-selection of individuals with specific skill sets for those occupations. To this end, we additionally include an interaction of fibre network with an indicator of skill intensity (Table A2, column 3).[6] The results presented in the last column of Table A2 suggest that while the employment effects of the availability of high-speed Internet on females in teleworkable occupations are robust to the selection of women by skills, wage response disappears (panel B). This suggests that the increase in relative wages for women attributed to digital connectivity observed in the base specification is indeed explained by those in high-skilled occupations, rather than their teleworkability per se.

Fourth, we turn to the data from the Household Labor Force Survey which report the frequency with which individuals work-from-home. While it provides a direct measure of WFH intensity, this dataset has a couple of shortcomings. It reports spatial units at a more aggregated level, i.e. NUTS2 regions, than the administrative linked employer-employee data, which weakens the identification assumption we employ in the empirical analysis. In addition, it reports occupations at a very aggregate level, making it infeasible to rely on an external measure of teleworkability. Therefore, we use the survey data to check the robustness of our main result, suggesting WFH as a relevant channel through which Internet connectivity improves relative female labor market outcomes. Our estimating equation is:

$$WFH_{it} = \gamma \text{Female}_i \times \text{Fibre}_{rt} + \Gamma X_i + \alpha_{sot} + \alpha^g_{ot} + \alpha_{rs} + \alpha_{rt} + \epsilon_i, \tag{5}$$

where i indexes individuals; r, o, and s denote the NUTS2 region, 2-digit ISCO occupation, and 2-digit NACE industry of the individual i, respectively. In the equation, α^g_{ot}

[6]Skill intensity is measured using the classification developed by Caunedo et al. (2023) who classify the O-NET occupational categories according to the usage of routine/non-routine, analytical/interpersonal skills. In particular, for each occupation, we calculate the simple average of their non-routine analytical (NRA) and non-routine interpersonal (NRI) skill measure. The ranking of this skill measure is intuitive: The occupation with the highest skill is Information Technology Trainers (2356) and the one with the lowest skill is Vehicle Cleaners (9122). Using this data we construct a dummy variable for high-skill occupations which have the average skill intensity above the mean across all occupations

denote gender specific occupation-time fixed effects which, among other factors, control for selection of men or women into certain occupations over time. We further include industry-occupation-time interacted fixed effects as well as region-industry fixed effects which control for the industry composition of regions. This specification is quite demanding as it also includes time-varying regional fixed effects which control for any time-varying demand- and supply-related factors at the regional level. The parameter of interest is γ.

Appendix Table A3 presents the results from estimating equation (5). Our results on the direct measure of WFH available in labor force surveys show that the interaction of Fibre with female dummy is positive and statistically significant (column 1), thereby implying increased probability of women working remotely post access to digital connectivity. This corroborates our baseline result in Table 2 based on the interaction of fiber with the teleworkability of occupations (columns 1 and 2). The interaction coefficient in Table A3 for the employment regression is negative and statistically significant (column 2), implying that the high-speed Internet in aggregate does not improve the labor market opportunities for women, a result broadly in line with the finding in Table 2 (column 1) where the coefficient for Fibre was found to be negative albeit statistically insignificant. Opportunities for females are heightened only in teleworkable occupations, a finding that we confirm using both the administrative data in Table 2 and here with the labor force survey data. Results obtained from the household level data also suggest that the estimated coefficient on the interaction of Fibre with female dummy for wages is positive (column 3), although not statistically different from zero. This is also consistent with the positive (and not significant) coefficient on Fibre in Table 2 (column 3).

4.4 Role of Skills

Given our earlier result that the effect of improvements in Internet connectivity on relative female earnings becomes insignificant once we control for skill level of workers, we

further explore the potential heterogeneity in effects with respect to skill composition of employment.

As reported in the previous subsection, the results of wage effects are driven primarily by women in high-skilled occupations. To investigate the role of skill for women's labor market gains from access to high-speed Internet, we re-run the most stringent specification for the two skill groups separately. For relative female employment, both skill groups in teleworkable occupations respond to the availability of the high-speed Internet, with a stronger response from women in the low-skill group (Table 3, columns 1 and 2). By comparison, only high-skilled women working in tele-workable occupations appear to obtain wage gains (Table 3, columns 3 and 4).

Table 3: Female labor Market Outcomes and High-Speed Internet: Results by skill groups

Dependent Variable:	Share of female employment		Relative female earnings	
	2SLS	2SLS	2SLS	2SLS
	Low-skill	High-skill	Low-skill	High-skill
	(1)	(2)	(3)	(4)
Teleworkability×Fibre	0.0450***	0.0134*	-0.0119	0.0309**
	(0.00807)	(0.00759)	(0.0116)	(0.0142)
Fixed Effects:				
Industry×Occupation×Time	✓	✓	✓	✓
Region×Industry	✓	✓	✓	✓
Region×Time	✓	✓	✓	✓
Observations	1,221,796	858,169	1,221,796	858,169

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

4.5 Transmission Mechanism

We now explore the underlying transmission mechanisms that can explain our baseline results. One potential channel could be that better digital connectivity motivates women

to switch occupations - from non-teleworkable to teleworkable - within a province. The linked employer-employee dataset allows us to track the movement of workers across jobs over time. The outcome of interest is the share of female workers in total employees that switch occupations in a given province between two consecutive years. We estimate the following equation:

$$\begin{aligned}
\text{Share of female switchers}_{odpt} &= \theta_1 \text{Non-Teleworkable}_o \times \text{Teleworkable}_d \times \text{Fibre}_{rt} \\
&+ \theta_2 \text{Teleworkable}_o \times \text{Teleworkable}_d \times \text{Fibre}_{rt} \\
&+ \theta_3 \text{Teleworkable}_o \times \text{Non-Teleworkable}_d \times \text{Fibre}_{rt} \\
&+ \alpha_{odt} + \alpha_{odr} + \alpha_{rt} + e_{odpt}, \qquad (6)
\end{aligned}$$

where the dependent variable is the share of female workers in total number of switchers between an origin occupation o and destination occupation d in region r in year t. As we include the region-time fixed effects, the base category is share of female workers in origin-destination occupation pairs that are both non-teleworkable.

Results obtained from estimating equation (6) are presented in Table 4. The results presented in column 1 suggest that women were more likely to change jobs to teleworkable occupations in provinces with the high-speed Internet. The estimated effect of high-speed Internet availability on the relative job mobility of female workers appears to vary with respect to the similarity in teleworkability between former and new jobs. In particular, the estimated effect is almost twice as large when the move is between two teleworkable occupations than when it is from a non-teleworkable occupation. This could be driven by the possibility that there are common set of skills required for teleworkable occupations.

Columns 2-3 of Table 4 split the sample based on the skill-intensity of the source occupations. The results are in line with those presented in the first two columns of Table 3. The share of women in low-skill occupations, who move to teleworkable occupations, increases with the improvement in Internet connectivity in a region. For women in high-

Table 4: Worker Movements within Provinces

Dependent Variable: Share of female movers	2SLS All (1)	2SLS Low-skill (2)	2SLS High-skill (3)
Non-Teleworkable$_o$ × Teleworkable$_d$ × Fibre	0.101**	0.110***	0.0357
	(0.0316)	(0.0375)	(0.0493)
Teleworkable$_o$ × Teleworkable$_d$ × Fibre	0.162***	0.335***	0.117***
	(0.0270)	(0.0647)	(0.0265)
Teleworkable$_o$ × Non-Teleworkable$_d$ × Fibre	0.0311	0.028	-0.0322
	(0.0325)	(0.0484)	(0.0268)
Fixed Effects:			
Source Industry × Destination Industry × Time	✓	✓	✓
Region × Source Industry × Destination Industry	✓	✓	✓
Region × Time	✓	✓	✓
Observations	633,614	351,299	261,421

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

skill occupations, their share in total number of movers increases with Internet connectivity only in cases where the move is between two teleworkable occupations. Combining this with our earlier results, these women also benefited from relative wage gains.

4.6 Is Investment in Digital Infrastructure Different from Other Types of Infrastructure Investment?

In this section, we investigate whether other types of infrastructure investments generate similar effects for women in the labor market. To do so, we exploit the large-scale public investment in roads in Türkiye during 2000s. The aim of the investment project was to expand the lane capacity of existing roads to improve safety and the reliability of travel times on the national transportation network through investments across the country. Specifically, a substantial share of existing two-lane single-carriageways with two-way

traffic were upgraded to dual carriageways separated by a small earthen medium, with two-lane one-way traffic on each carriageway.[7]

Our aim is to study whether the large-scale public investment in roads generated similar gains for female workers to the one we have exploited so far, which led to improvements in internet connectivity. To compare the effects generated by the two investment episodes, we need to introduce some changes in our empirical setting. For the road investment program, due to data availability, we can only estimate long-term effects, i.e. between 2005-2015. Our variable of interest is the population-weighted average of bilateral travel time reductions between 2005 and 2015 for each district in Turkiye:[8]

$$\Delta \ln \text{Travel Time}_d^{Wgt} = \sum_{d'} \ln \left(\frac{\text{Travel Time}_{dd',2015}}{\text{Travel Time}_{dd',2005}} \right) \text{Population share}_{d',2005} \tag{7}$$

This measure that is inversely related to changes in market access for districts.

Another important difference in data availability for the road infrastructure period is that the administrative linked employer-employee data does not report the occupation codes for workers. Therefore, to investigate the role of WFH, we will exploit industry heterogeneity.

Our estimating equation is as follows:

$$\begin{aligned} \Delta(\text{Share of female employment})_{ds} &= \eta_1 \Delta \ln (\text{Travel time})_d^{Wgt} + \eta_2 \ln \text{Distance}_d^{Wgt} \\ &+ \eta_3 \text{Teleworkability}_s * \Delta \ln (\text{Travel time})_d^{Wgt} \\ &+ \eta_4 \text{Teleworkability}_s * \ln \text{Distance}_d^{Wgt} \\ &+ \eta_5 \text{Female intensity}_s * \Delta \ln (\text{Travel time})_d^{Wgt} \\ &+ \eta_6 \text{Female intensity}_s * \ln \text{Distance}_d^{Wgt} \\ &+ \alpha_s + \alpha_p + \epsilon_{ds}, \end{aligned} \tag{8}$$

[7] See Cosar et al. (2021) for details of the investment program.

[8] Turkey is administratively divided into 81 provinces, which are further divided into districts.

where the dependent variable is the period change (i.e. 2006-2016) in the ratio of female employment to total employment in industry s and district d. Aggregate province- and industry-level changes are controlled by including α_p and α_s. $\ln \text{Distance}_d^{Wgt}$ and $\ln(\text{Travel time})_d^{Wgt}$ denote the population-weighted average of bilateral distance and period-change in bilateral travel times at the district level.[9] The former controls for the initial connectivity of districts. Since our specification controls for provincial fixed effects and initial remoteness of the district, we exploit "unexpected" or "random" variation in improvements in remoteness of the district due to the road infrastructure investments. We also include interactions with female employment intensity at the industry level to run a horse race with our teleworability measure which is constructed by Dingel and Neiman (2020b).

5 Conclusion

Our study highlights the potential role of the availability of high-quality digital infrastructure in enhancing gender equality in labor markets. Exploiting the staggered roll-out of fibre cable Internet in Türkiye during the 2010s and using rich administrative worker-level data, we find that high-speed Internet led an increase in relative female employment and wages, thereby contributing to the narrowing of the gender gap. In particular, the availability of high-speed Internet has facilitated an increase in female employment in teleworkable occupations, pointing to work-from-home opportunities as a potential channel.

Our results also suggest that the employment gains for women from the availability of high-quality Internet originated from switches towards teleworkable occupations, rather than from an increase in female labor force participation. While both low- and high-skilled women increased their employment shares, the wage gains were accrued only to

[9]The empirical specification as well as the construction of variables of interest follow the approach in Cosar et al. (2021).

Table 5: Female Labor Market Effects of Internet and Road Infrastructure Investments

Dependent Variable: Change in female	employment share (1)	relative earnings (2)	employment share (3)	relative earnings (4)
Teleworkability×Fibre	0.00843*	0.0233***		
	(0.00480)	(0.00686)		
Female intensity×Fibre	-0.00332	0.0666***		
	(0.0128)	(0.0144)		
$\Delta \ln$ (Travel time)^{Wgt}			0.298**	0.195
			(0.117)	(0.219)
ln Distance^{Wgt}			0.0108***	0.00212
			(0.00372)	(0.00514)
Teleworkability$\Delta \ln$ (Travel time)^{Wgt}			0.0948	0.227
			(0.133)	(0.149)
Teleworkabilityln Distance^{Wgt}			-0.00511*	0.00190
			(0.00274)	(0.00326)
Female intensity$\Delta \ln$ (Travel time)^{Wgt}			-0.190	-0.138
			(0.393)	(0.480)
Female intensityln Distance^{Wgt}			-0.00350	-0.00552
			(0.00764)	(0.00910)
Fixed Effects:				
Industry×Occupation×Time	✓	✓		
Region×Time	✓	✓		
Region×Industry×Occupation	✓	✓		
Province			✓	✓
Industry			✓	✓
Observations	2,165,388	2,165,388	54,288	54,288

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

high-skilled women. Low-skill women have transitioned from non-teleworkable to teleworkable jobs, which has increased their employment opportunities but has also led to a decrease in their wages. Conversely, high-skill women have moved within teleworkable occupations to higher-paying positions, reflecting a positive wage effect for this group.

Overall, our paper contributes to the broader literature on the economic impacts of

Internet access, providing robust evidence that investments in digital infrastructure can play a pivotal role in promoting gender equality in labor markets. This research provides valuable insights for policymakers and development finance institutions (DFIs) on how to leverage digital infrastructure investments to promote gender equality in labor markets. To facilitate work-from-home as a viable option for women once they have digital connectivity, several aspects need to be addressed. *Firstly*, social norms ought to recognize and support the value of remote work, especially for women. This can be achieved through awareness campaigns, promoting positive role models, and highlighting the benefits of bringing women into the workforce through flexible work arrangements. Additional considerations would be required to update the legal regulations to ensure that women have equal access to remote work opportunities, parental leave, and protection against discrimination. Moreover, digital data protection and cyber security measures need to be strengthened to build trust and confidence in remote work arrangements, ensuring the privacy and security of information.

Complementary investments in skills, mentoring, and training are crucial to close the digital gap for women, especially considering the heterogeneous effects of digital connectivity based on skills. Policymakers should prioritize initiatives that provide women with the necessary digital skills and knowledge to fully participate in the digital economy. Concerted efforts in promoting digital literacy and access to technology might be required, particularly in underserved communities, to address the gender digital divide. By equipping women with the skills and resources needed to leverage digital connectivity, policymakers can ensure that they can fully benefit from the opportunities presented by investments in digital infrastructure.

Given that the gains from digital connectivity are mediated through women's ability to switch occupations, policies, reforms, and interventions are needed to enable and support this process. Policymakers ought to consider the ingredients of an enabling environment that promotes occupational mobility for women. This can involve implementing

labor market reforms that reduce barriers to entry and promote job flexibility, such as flexible work arrangements, and job matching platforms. Additionally, policies should be designed to address occupational segregation and promote gender diversity in traditionally male-dominated industries. This can include targeted initiatives to encourage women's participation in STEM fields and other high-growth sectors. Furthermore, access to information and resources on job opportunities, career development, and networking should be enhanced to empower women to make informed decisions and navigate occupational transitions successfully.

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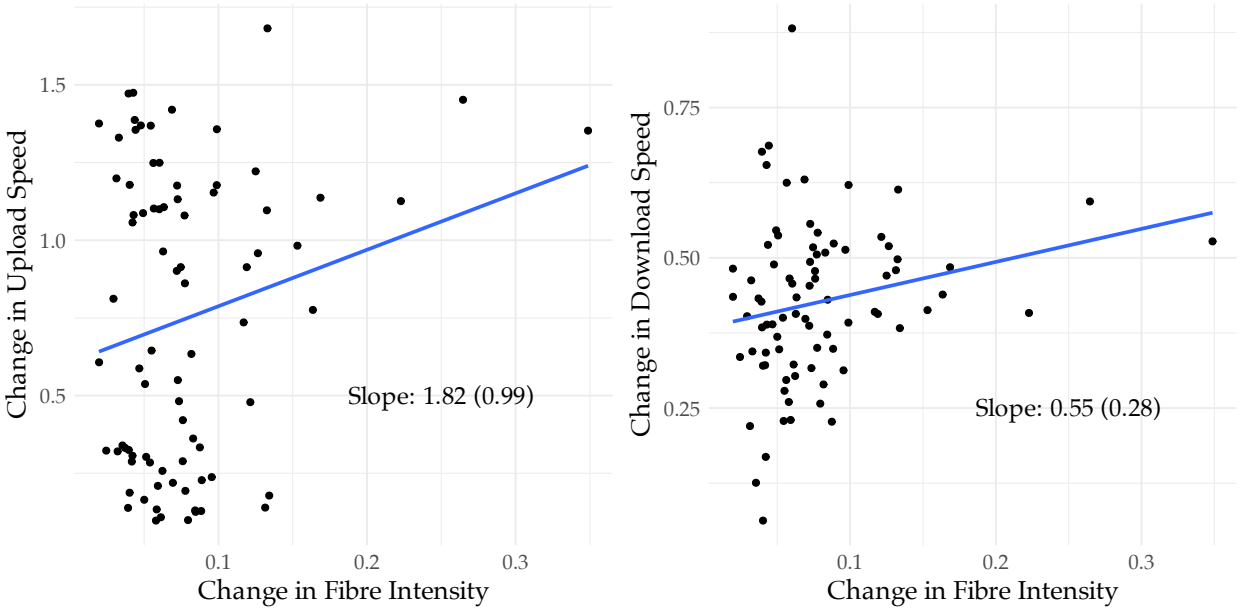
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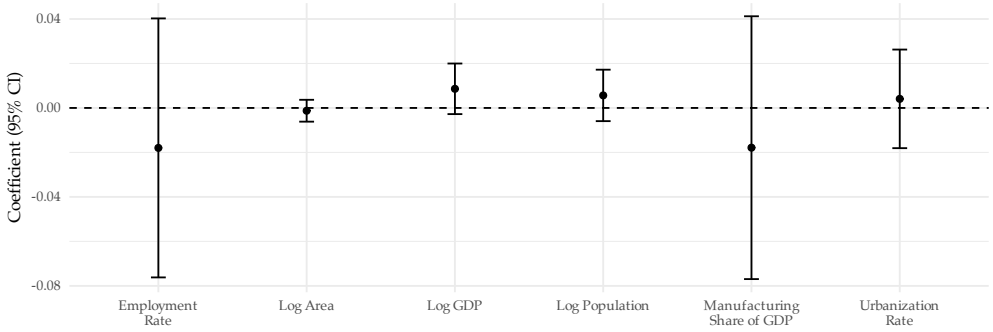
A Additional Tables and Figures

Figure A1: **Correlation of Fibre Intensity with Upload and Download Speeds**



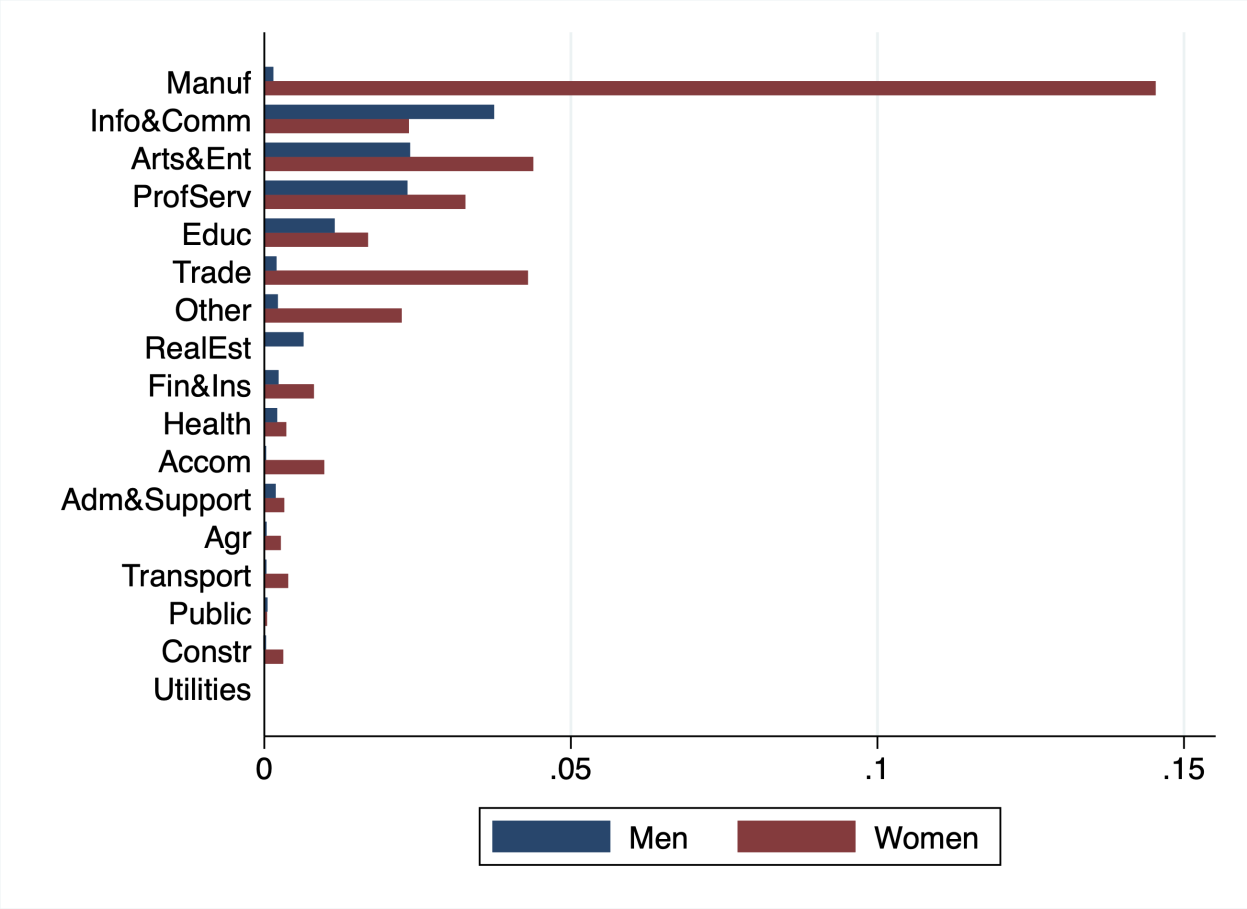
Note: The left panel depicts how change in measured fibre intensity correlates with change in reported upload speeds during the period 2016-2019. The right panel depicts correlation of fibre intensity with reported download speeds. Data on upload and download speeds across Turkish provinces during 2016-2019 was obtained from Ookla, a private firm.

Figure A2: Distance to BOTAS pipelines and Initial Province Characteristics



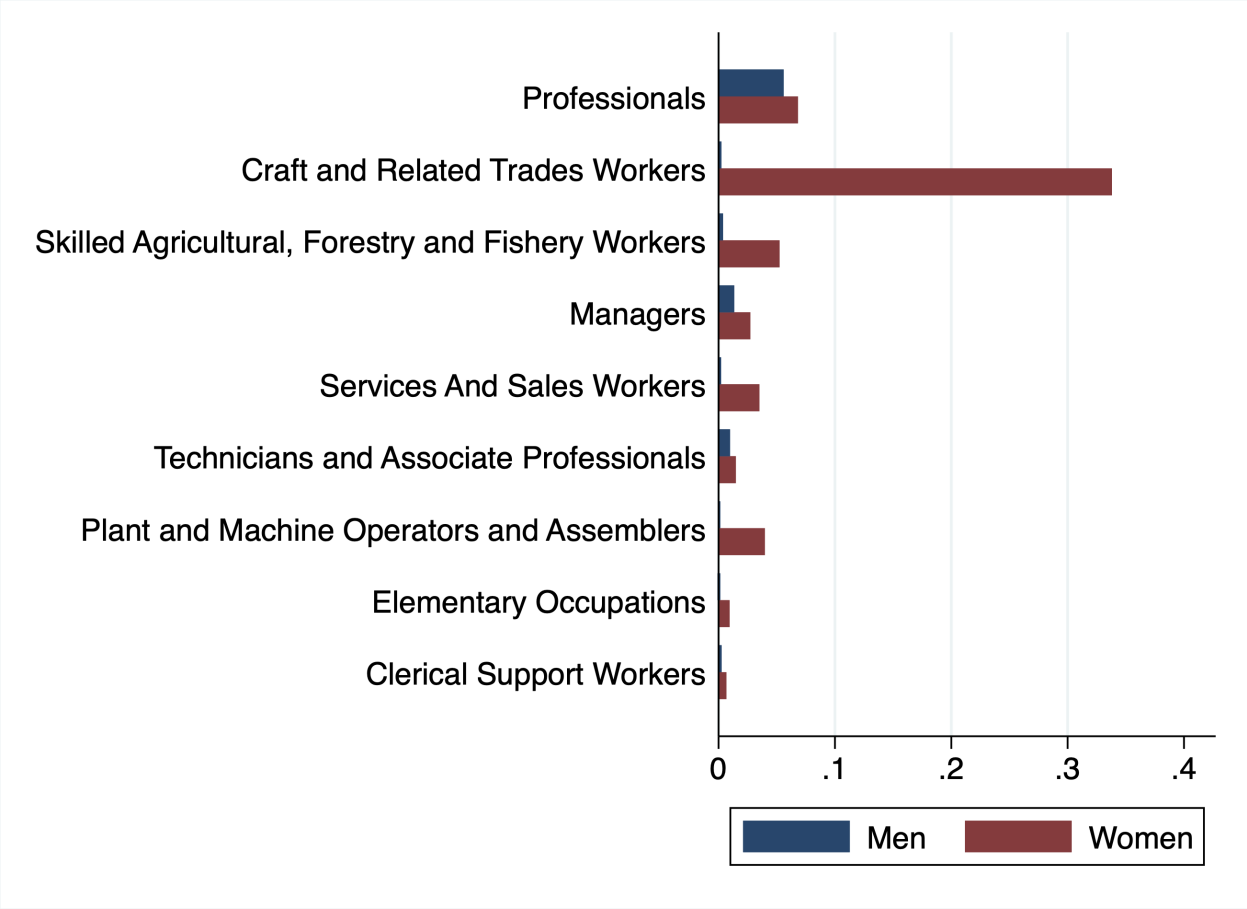
Note: The distance of a province to BOTAS pipelines is constructed as the weighted average of the distances of districts within the province where the district population are used as weights. This figure plots the coefficient estimates and the corresponding 95% confidence intervals obtained from regressing this distance on initial provincial characteristics (pertaining to 2011), controlling for NUTS2 level fixed effects.

Figure A3: WFH Intensity by Industry and Sex



Note: The figure shows the fraction of respondents to the Household labor Survey, who, at least, partly work-from-home.

Figure A4: WFH Intensity by Occupation and Sex



Note: The figure shows the fraction of respondents to the Household labor Survey, who, at least, partly work-from-home.

Table A1: Employment and High-Speed Internet

Dependent Variable: Log of employment						
	OLS		2SLS		2SLS	
	Full sample		Full sample		TW occupations	Non-TW occupations
	(1)	(2)	(3)	(4)	(5)	(6)
Fibre	0.378***		0.834***			
	(0.0844)		(0.275)			
Female×Fibre	0.0364	0.0367	0.0103	0.0105	0.0306***	-0.00998
	(0.0293)	(0.0294)	(0.0122)	(0.0123)	(0.0103)	(0.0151)
Fixed Effects:						
Gender×Occupation×Time	✓	✓	✓	✓	✓	✓
Industry×Occupation×Time	✓	✓	✓	✓	✓	✓
Region×Industry	✓	✓	✓	✓	✓	✓
Region×Time		✓		✓	✓	✓
Observations	3,490,367	3,490,367	3,490,367	3,490,367	1,208,553	2,109,946

Note: Columns 1 and 3 also include time-varying regional characteristics such as GDP per capita. They are not reported to save space. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

Table A2: Female labor Market Outcomes and High-Speed Internet: Robustness checks

	2SLS	2SLS	2SLS
	(1)	(2)	(3)
Panel A			
Dependent Variable: Share of female employment			
Teleworkability×Fibre	0.0154***	0.025***	0.0289***
	(0.00199)	(0.006)	(0.00666)
Female intensity×Fibre	-0.0178		
	(0.0158)		
High skill×Fibre			0.00143
			(0.00462)
Panel B			
Dependent Variable: Relative female earnings			
Teleworkability×Fibre	0.0327**	0.035**	0.0121
	(0.0134)	(0.014)	(0.0115)
Female intensity×Fibre	0.0653***		
	(0.0143)		
High skill×Fibre			0.0639***
			(0.0108)
Fixed Effects:			
Industry×Occupation×Time	✓	✓	✓
Region×Industry	✓		✓
Region×Time	✓	✓	✓
Region×Industry×Occupation		✓	
Observations	3,490,367	3,490,367	3,490,367

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported

Table A3: Work-from-Home and High-Speed Internet: Effect on women

Dependent Variable:	WFH	Employment	Log of wage
	2SLS	2SLS	2SLS
	(1)	(2)	(3)
Female×Fibre	0.00670***	-0.0262***	0.00664
	(0.00175)	(0.00403)	(0.00607)
Fixed Effects:			
Industry×Occupation×Time	✓	✓	✓
Gender×Occupation×Time	✓	✓	✓
Region×Industry	✓	✓	✓
Region×Time	✓	✓	✓
Observations	650,071	3,595,465	650,071
KP Test stat.	30.05	18.19	30.05

Note: All specifications control for individual characteristics such as gender, age, age squared, education, marital status. They also control for initial income per capita, interacted with annual dummies and with time-varying gender dummies. They are not reported to save space. * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the regional-time level, are reported in parentheses.

B Road Infrastructure and Female Employment

In this section, we investigate whether other types of infrastructure investments generate similar effects for women in the labor market. To do so, we exploit the large-scale public investment in roads in Türkiye during 2000s. The aim of the investment project was to expand the lane capacity of existing roads to improve safety and the reliability of travel times on the national transportation network through investments across the country. Specifically, a substantial share of existing two-lane single-carriageways with two-way traffic were upgraded to dual carriageways separated by a small earthen medium, with two-lane one-way traffic on each carriageway.[10]

Such large-scale public investment program could potentially trigger gendered changes in labor market outcomes through a number of channels. *First*, there could be an overall scale effect in Turkish regions, which benefited more from this investment due to improved *market access*. To the extent that the newly generated employment opportunities have a gender bias, this could affect relative female employment and wages. *Second*, road investments could lead to across district *agglomeration spillovers* because shorter inter-district commuting times increase women's ability to engage in employment opportunities outside of their home districts. *Lastly*, if better connected districts are in the vicinity of other populated districts, then it may crowd out opportunities for local females due to *competition effect*. Therefore, the overall effect of reductions in travel times generated by this large-scale road investment project on female labor market outcomes is ambiguous.

To investigate whether the road investment program generated heterogeneous employment effects for men and women, we estimate the following specification:

$$\begin{aligned}\Delta(\text{Share of female employment})_{ds} &= \mu_1 \Delta \ln(\text{Travel time})_d^{Wgt} + \mu_2 \ln \text{Distance}_d^{Wgt} \\ &+ \mu_3 \Delta \ln(\text{Commute time})_d \\ &+ \mu_4 \Delta \ln(\text{Population within 2hr commute time})_d\end{aligned} \tag{9}$$

[10] See Cosar et al. (2021) for details of the investment program.

$$+ \quad \alpha_s + \alpha_p + \epsilon_{ds},$$

where the dependent variable is the period change (i.e. 2006-2016) in the ratio of female employment to total employment in industry s and district d.[11] Aggregate province- and industry-level changes are controlled by including α_p and α_s. $\ln \text{Distance}_d^{Wgt}$ and $\ln (\text{Travel time})_d^{Wgt}$ denote the population-weighted average of bilateral distance and period-change in bilateral travel times at the district level.[12] The former controls for the initial connectivity of districts while the latter is one of our variable of interest which is inversely related to changes in market access. Since our specification controls for provincial fixed effects and initial remoteness of the district, we exploit "unexpected" or "random" variation in improvements in remoteness of the district due to the road infrastructure investments.

The third variable, $\Delta \ln (\text{Commute time})_d$, is the change in the logarithm of travel time to the most populated district within a two-hour commute time. This captures the improvements in job opportunities nearby for individuals living in district d. The last variable, $\Delta \ln (\text{Population within 2hr commute time})_d$, captures the change in the potential workforce living within a two-hour commute from district d. We expect $\mu_3 > 0$ as women could be more sensitive to commute times than men. The sign of μ_4 is ambiguous as it captures the competition in the labor market. If female workers are less able to stand competition from nearby districts, the sign of the coefficient would be negative.

We exclude from the estimation sample the four provinces with highways in the beginning of the period, namely Ankara, Istanbul, Izmir, and Mersin. Standard errors are clustered at the province level.

Results are presented in Table A4. In the first two columns, the outcome of interest is the period change in the share of female employment. The first column only includes our proxy for change in the weighted average of travel times and initial remoteness of

[11] Turkey is administratively divided into 81 provinces, which are further divided into districts.

[12] The empirical specification as well as the construction of variables of interest follow the approach in Cosar et al. (2021).

Table A4: Share of Female Employment and Improvements in Market Access

Dependent Variable: Change in female	employment share (1)	employment share (2)	relative earnings (3)	relative earnings (4)
$\Delta \ln(\text{Travel time})^{Wgt}$	-0.133	-0.605**	-0.429	-0.584
	(0.246)	(0.279)	(0.325)	(0.464)
$\ln \text{Distance}^{Wgt}$	-0.00423	-0.0122**	-0.00938	-0.0126
	(0.00593)	(0.00603)	(0.0112)	(0.0115)
$\Delta \ln(\text{Commute time})$		0.0833***		0.0189
		(0.0297)		(0.0407)
$\Delta \ln(\text{Population within 2hr commute time})$		-0.0157*		-0.00807
		(0.00935)		(0.0167)
Fixed Effects:				
Province	✓	✓	✓	✓
Industry	✓	✓	✓	✓
Observations	6292	6292	6292	6292

Note: * 10%, ** 5%, *** 1% significance levels. Standard errors, clustered at the province level, are reported in parentheses.

district. The estimated coefficient on the former has the expected sign but it is not statistically significant. This could be due to the omission of measures that capture changes in commuting costs as they are correlated with the change in market access. The second column shows the estimated coefficients from the full model. The coefficient on the market access variable is negative and statistically significant, implying that improvements in market access are associated with an increase in female employment share. By comparison, shorter commute times to the most populated district increase women's employment opportunities across districts, thereby reducing their share within the home district. This is consistent with the hypothesis that women are more sensitive to commute times and can seek employment opportunities in nearby locations when commute times improve. Finally, the competition effect, induced by reductions in commuting times to d from nearby districts, seems to hurt female workers more. The crowding out effect we find in our empirical setting is consistent with the existing literature, e.g. Chandra and Thompson (2000) – despite the lack of focus on gender-specific effects, and more recently with the results in Erten and Keskin (2021).

Using the estimates, we calculate a size-weighted, that is, size being measured in terms of the initial district-level population, aggregate effect of reduced inter-district travel times on the share of female employment. We find the effect to be about 6 percentage points, which is slightly less than a third of the aggregate female employment share in Turkey.

In columns 3-4 of Table A4, the dependent variable is the period change in relative earnings of female workers in an industry-district pair. The estimated effects on wages have the same sign as those on employment. However, they are imprecisely estimated.

Overall, what we learn from this exercise is that when comparing the effects of road infrastructure investments with that of digital infrastructure in reducing gender disparities, our analysis suggests that the latter has a clear positive impact on female labor market outcomes, the impact of road infrastructure is more nuanced. Improvements in market access through road infrastructure are associated with an increase in female employment share, shorter commute times to the most populated district and competition effects from proximate districts can reduce female employment share within the district.