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Yusuf Emre Akgunduz,(1) Ayse Karasoy,(2) Gokce Karasoy Can(3) and Elif Ozcan Tok(4)

## Abstract

This paper investigates how pre-pandemic investments in digital technologies influenced firm performance during the Covid-19 crisis and subsequent recovery, using comprehensive administrative data from Türkiye. We construct a novel firm-level digitalisation index based on firm-to-firm trade transactions, capturing a broad spectrum of digital investments including software, hardware, consultancy, and data services. Employing coarsened exact matching and a difference-in-differences framework, we find that more digitalised firms outperformed their less digitalised pairs during the pandemic and post-pandemic years. Specifically, digitalised firms exhibited 3% higher total assets, 4% higher net sales, and 2% higher employment, with even greater gains in profitability (0.44 percentage points), return on assets (0.42 percentage points), and export share (0.16 percentage points). To investigate plausible mechanisms consistent with these effects, we examine whether more digitalised firms expanded their trade networks, experienced lower worker turnover, and achieved higher productivity during the pandemic. We find that these firms added 3% more partners and traded over 2% greater distances with reduced labour churn, and higher productivity. These findings underscore the role of digitalisation in enhancing firm resilience and adaptability in the face of economic shocks.

**Key words:** Digitalisation, Covid-19, coarsened exact matching, differences-indifferences, firm performance.

**JEL classification:** C55, D22, O33.

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# 1 Introduction

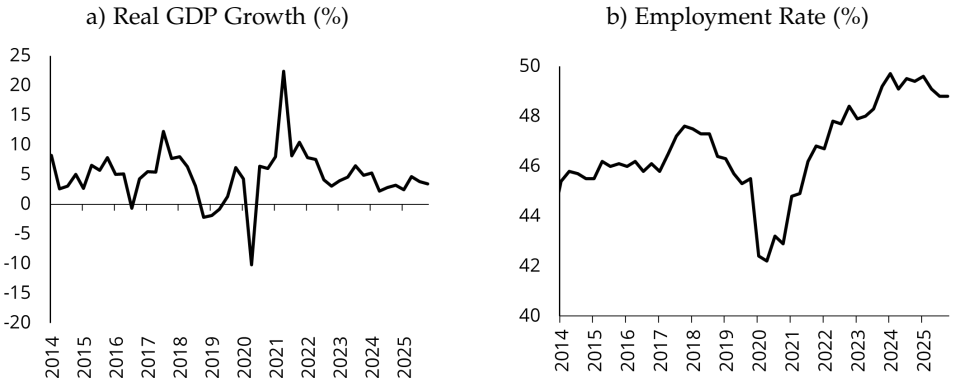
Digital technologies are widely believed to enhance firms' flexibility, productivity, and market reach. Yet empirical evidence on whether digitalization improves firms' resilience to large economic shocks remains limited. The COVID-19 pandemic provides a unique opportunity to study this question, as lockdowns, mobility restrictions, and supply chain disruptions dramatically increased the value of digital tools such as online platforms, digital communication technologies, and remote working systems.

Across the world, firms experienced sharp declines in sales and revenues during the pandemic and faced severe disruptions to supply chains and labor markets.[1] At the same time, digital technologies became essential for maintaining business operations, enabling firms to adopt remote working arrangements, reach customers through online channels, and coordinate production and logistics under physical restrictions. The pandemic therefore provides a natural setting to examine whether firms that had invested in digital technologies prior to the pandemic performed better and showed greater resilience during an unprecedented global shock.

In this paper, we empirically investigate this question to better understand the role of digitalization as a buffer against economic shocks and to inform policy discussions on digital transformation in the post-pandemic economy. Our study uses rich administrative firm-level data from Türkiye, including balance sheets, employment records, and firm-to-firm trade transactions. These datasets allow us to construct a novel index of firm-level digitalization based on firms' purchases of digital goods and services from information and communication technologies (ICT) producing sectors. By tracking actual inter-firm transactions in digital equipment, software, telecommunications, and related services, this index captures a broad range of digital investments from hardware and software to digital services and consultancy. Variation in digitalization across firms is substantial in Türkiye's economy, providing a useful setting to study the effect of pre-pandemic digitalization on firm performance during the COVID-19 crisis. The pandemic had a profound impact on economic activity in Türkiye. Gross domestic product (GDP) and employment declined sharply in early 2020 as exports, tourism, and domestic demand collapsed (Figure 1). The government responded with a range of fiscal and monetary policy measures to mitigate the economic fallout. Despite these interventions, many firms faced severe liquidity constraints and operational disruptions.

[1] The negative effects of the pandemic are extensively documented by Acharya and Steffen, 2020; Beck et al., 2020; Fairlie, 2020; Demmou et al., 2021; Banerjee and Kharroubi, 2020; IMF, 2021.

Figure 1: GDP Growth and Employment




Firms that invested more heavily in digital technologies prior to the pandemic are classified as more digitalized, while firms with lower levels of such investment serve as the control group. We then implement a coarsened exact matching (CEM) procedure to pair each highly digitalized firm with a comparable less-digitalized firm based on key pre-2020 characteristics including industry, size, age, total assets, net sales, export share, and employment. We employ a difference-in-differences (DID) framework to estimate the causal impact of digitalization on firm performance during the pandemic and the immediate recovery period (2020–2021).

Our results show that firms with higher pre-pandemic digitalization levels significantly outperformed their less digitalized pairs during the pandemic and post-pandemic period. Digitalized firms experienced stronger growth in assets, sales, and employment by 3%, 4% and 2%, respectively. More digitalized firms achieved greater improvements in profitability, return on assets (ROA), and export share, with effects ranging from approximately 0.16 to 0.44 percentage points. These performance gaps emerged during the pandemic year of 2020 and persisted into the recovery year of 2021, suggesting that digitalization enhanced firms' resilience to the shock and reduced longer-term scarring effects.

We further explore several mechanisms through which digitalization may have contributed to improved firm performance. In particular, we analyze three channels: trade network expansion, labor market dynamics, and productivity. First, we examine whether digitalization helped firms maintain and expand their trade relationships during the pandemic. Using firm-to-firm trade data, we find that more digitalized firms expanded their number of trading partners and engaged with partners at greater geographic distances. They were better able to maintain supply chain relationships during the disruption. Second, we analyze labor market dynamics and show that more digitalized firms experienced lower worker turnover and higher employee retention during the pandemic and post-pandemic period, consistent with the widespread adoption of remote work and more flexible work arrangements (Barrero et al., 2021) and the suggestion that digitalization improves job stability (Arntz et al., 2016).[2] Third, we document higher productivity

[2] A related literature studies how digital technologies and automation reshape labor demand and skill composition within firms (Autor et al., 2003; Acemoglu and Restrepo, 2018; Balsmeier and Woerter, 2019).

growth among digitalized firms during the pandemic and recovery years. This result aligns with a broad literature which has previously examined the adoption of digital technologies and their implications for productivity, innovation, and firm growth (e.g., Andrews et al., 2016; Gal et al., 2019; Cette et al., 2022).

Recent studies have examined the role of digitalization in shaping firm resilience during economic shocks (e.g., Nose and Honda, 2023; Abidi et al., 2022; Copestake et al., 2024; Lim and Morris, 2023). Much of this literature relies on survey data or sector-level measures of digital adoption (e.g., Autio et al., 2022; Bouwman et al., 2018; Heredia et al., 2022), which may not capture firm-level heterogeneity. By contrast, our approach uses detailed administrative firm-to-firm transaction data to construct a direct measure of firms' purchases of digital goods and services, enabling us to capture firm-level variation in digital investment with greater precision than survey-based measures.

The closest studies to ours are Abidi et al. (2022), and Copestake et al. (2024). These studies similarly estimate the effect of digitalization on firm performance during and after the pandemic. Abidi et al. (2022) rely on survey data to estimate the effects on firm sales. Their results suggest that digitalized firms were more resilient during the pandemic downturn. Copestake et al. (2024) use sector-level digitalization measure from Calvino et al. (2018) to estimate the effects on sales and validate their results with various metrics such as the share of sectoral digital inputs from input-output tables, the share of intangibles from balance sheets, and the relative frequency of digital skills on LinkedIn profiles. They also report an increase in firm resilience and further conclude that digitalization helps limit scarring effects of negative shocks.

Building on a direct measure of firms' purchases of digital goods and services, this paper makes three main contributions to the literature on digitalization and firm performance. First, we construct a novel firm-level digitalization index using administrative firm-to-firm transaction data. This index encompasses a range of investments, including equipment, software, licenses, and consultancy services, thus providing a more nuanced view of digitalization's impact on firm performance. Second, we provide causal evidence on the role of digitalization in enhancing firm resilience during the COVID-19 shock. Third, we exploit the richness of administrative data to investigate several mechanisms through which digitalization affects firm performance, including trade network expansion, labor market dynamics, and productivity.

The remainder of the paper is organized as follows. Section 2 describes the institutional background and data sources. Section 3 explains the construction of the digitalization index. Section 4 outlines the empirical strategy. Section 5 presents the baseline results. Section 6 explores the mechanisms. Section 7 reports robustness checks, and Section 8 concludes.

## 2 Data

We primarily use two administrative datasets. The definitions and sources of the data and the variables constructed are available in the Appendix, in Table A.1. The first dataset is comprised

of balance sheet and income statements of all Turkish firms for the 2009 - 2021 period provided by the Firm Tax Registry. Firms that operate under the regular corporate income tax regime have to report balance sheet and income statements. Other firms that operate under the personal income tax regime have this obligation if their annual gross sales or revenues exceed particular thresholds.[3] The balance sheets and income statements are reported to the Firm Tax Registry on an annual basis. From this dataset, we derive firm level total assets, sales, profits, employment and export share. Assets and net sales are deflated by the Consumer Price Index (CPI) and then log-transformed. Employment is defined as the log of total number of employees. Export share is calculated by export sales divided by gross sales. Firm age is calculated as the time elapsed since the establishment date. Profitability is defined as net profits over total assets, return on assets is operating income before depreciation over total assets. Firms with negative assets or net sales are dropped from the data to disregard economically inactive firms that remain in tax records. We further trim each variable in each tail by one percent at the NACE Rev-2 digit sector level.

We construct productivity indicators from balance sheet variables. Productivity is defined as sales per employee or as sales over assets. Furthermore, categorical variables are constructed from the original variables by dividing them into deciles at the two-digit sector-year level. This allows us to investigate whether the relative place of the firm changes following digitalization.

The second dataset is the firm-to-firm trade data provided by the Revenue Administration that we employ to construct the firm-level digitalization index. These data include all transactions over 5,000 Turkish Lira with domestic firms. These transactions are reported by firms to the Ministry of Treasury and Finance for value added tax purposes. Firm-to-firm trade data contains information on the identification numbers and 4-digit level sectors of the firms on both sides of the transaction, the value of the transaction and the supplier's country on a monthly basis for 2009-2021 period.

In order to investigate the labor market effects, we make use of data provided by the Social Security Institution showing the information of 4A employees since 2009. This allows us to track individual-firm pair salaries, entries to and exits from the firm. From this data, we calculate the average salary level, new hires rate and separations rate as well as the churn rate (calculated as the sum of new hires and separations divided by total number of employees) for each firm-year observation.

Finally, we use inter-province distance information for Turkish provinces to create network variables. The General Directorate of Highways provides inter-province distances in kilometers. We then build sales-weighted distance for each firm.

[3] In 2021, the thresholds of the annual purchases or gross sales for the firms that sell the goods without processing or after processing were 280,000 TL and 420,000 TL, respectively. For other firms, the threshold for annual revenue was 150,000 TL.

## 3 Construction of Digitalization Index

Digitalization refers to the incorporation of digital tools and technologies into a firm's operational and management framework. Investment in digitalization is not restricted to equipment and software purchases. It also includes services, consultancy and maintenance, all of which are essential to realize its full benefits. Therefore, digitalization involves a variety of technologies and processes that affect multiple aspects of firm activity. This complex nature makes it difficult to create a one-size-fits-all measure.

Most of the existing studies conduct surveys and questionnaires about the firms' involvement in e-commerce, remote working schemes, and investment in information and communication technologies (Autio et al., 2022; Bouwman et al., 2018). These survey based measures carry with them some level of subjectivity and representativeness problems. Nose and Honda (2023) construct a firm-level digitalization index using balance sheets and income tables. They calculate the index by taking the firm's output and assets and multiplying them by the share of intermediate inputs sourced from the digital industry relative to the total intermediate inputs in the firm's sector. Hence, digitalization is measured at the sector level, and the firm level variation is driven by firm size. We take this approach one step further by using micro-level firm-to-firm trade data.

We first identify the sectors that provide digital products and services (Table 1). Digitalization is not limited to the purchase of physical equipment. A broad measure should involve investments into equipment and software, communications, data services, consultancy, and maintenance services to ensure technology is used effectively.[4] Therefore, we aim to cover all relevant sectors of digital investment including manufacture and sale of computers and equipment, communication technologies, software, programming and consulting activities.

For each firm and each year, we compute the total purchases from these sectors and divide by CPI to obtain real values.[5] We then aggregate these real purchases over the 2015-2019 period. Some firms may only be active during part of this period; in such cases, the calculation is based solely on the years in which the firm was active. To account for firm size, we scale each firm's real digital purchases by dividing them by the total number of employees during the same period. Consequently, we construct a digitalization index by calculating real digital purchases per employee:

$$digitalization_i = \frac{\sum_{t=2015}^{2019} \sum_j real\ purchase_{j,i,t}}{\sum_{t=2015}^{2019} number\ of\ employees_{i,t}}$$

where $i$ represents the firm, $t$ refers to the year. $j$ is the partner firm operating in one of the digital products and services providing sectors. The majority of firms have zero digital purchases in

[4] See Dhyne et al. (2021) and Amiti et al. (2024).

[5] Ideally, an ICT specific price index would better capture the rapid decline in prices of ICT goods and services over time. However, such an index is not available in our dataset or from official sources.

Table 1: Digital Products and Services Sectors

| NACE4 Code | Sector Definition |
|---|---|
| 2620 | Manufacture of computers and peripheral equipment |
| 2630 | Manufacture of communication equipment |
| 4651 | Wholesale of computers, computer peripheral equipment and software |
| 4652 | Wholesale of electronic and telecommunications equipment and parts |
| 4741 | Retail sale of computers, peripheral units and software in specialized stores |
| 4742 | Retail sale of telecommunications equipment in specialized stores |
| 5829 | Other software publishing |
| 6110 | Wired telecommunications activities |
| 6120 | Wireless telecommunications activities |
| 6130 | Satellite telecommunications activities |
| 6190 | Other telecommunications activities |
| 6201 | Computer programming activities |
| 6202 | Computer consultancy activities |
| 6203 | Computer facilities management activities |
| 6209 | Other information technology and computer service activities |
| 6311 | Data processing, hosting and related activities |
| 6312 | Web portals |
| 7733 | Renting and leasing of office machinery and equipment (including computers) |
| 7740 | Leasing of intellectual property and similar products, except copyrighted works |

*Notes: This table presents the names and 4-digit NACE codes for the list of sectors that we define as digital goods and services providing, which are used to construct the variable 'digitalization'.*

2015-2019. The summary statistics of the digitalization measure we constructed are provided in Table 2.

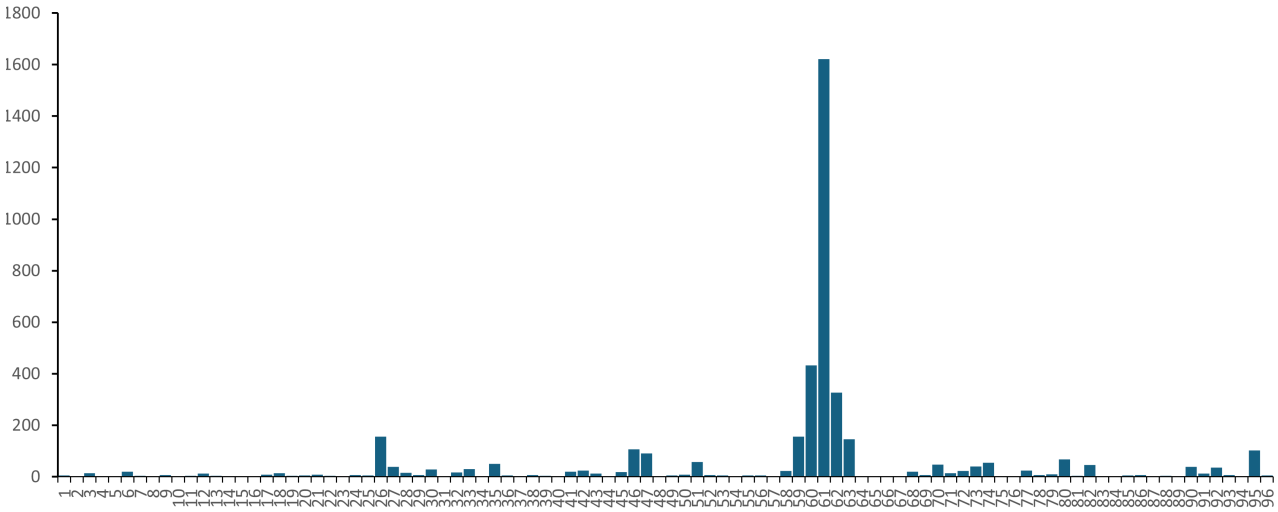
Table 2: Summary Table for Digitalization

| | Mean | SD | p5 | p10 | p25 | p50 | p75 | p95 | p99 | # of Obs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Digitalization | 51.66 | 2184.18 | 0.00 | 0.00 | 0.00 | 0.00 | 2.28 | 53.45 | 710.39 | 541,562 |

*Notes: This table presents summary statistical data pertaining to the variable digitalization. The statistics have been derived from the complete dataset utilized in the construction of the digitalization variable, which is defined as the average expenditure on digital goods and services per employee over the period 2015-2019.*
*Source: Revenue Administration, Authors' calculations.*

As illustrated in Figure 2, the constructed digitalization index varies considerably across sectors. The highest average values are observed in Sectors 59, 60, 61, 62, and 63, which broadly correspond to telecommunications, broadcasting, information technology services and data processing where digital infrastructure and services are core to business operations. Elevated levels are also found in wholesale and retail trade (Sectors 46 and 47), likely reflecting the growing role of digital products in logistics, inventory management, and e-commerce platforms. Additionally, Sector 26 (manufacture of computer, electronic and optical products) and Sector 95 (repair of computers and personal goods) show relatively high digital purchases, which is consistent with their technological intensity.

Figure 2: Average of Digitalization Index across Sectors




By leveraging detailed administrative records rather than potentially subjective survey responses, this index reduces measurement error and sampling bias. It captures differences at firm level by offering a detailed view of a firm's digital investments. This measure accounts for a wide spectrum of digitalization investment, ranging from tangible assets like digital equipment and machinery to intangible costs such as software licenses, data management expenses and consultancy fees. This comprehensive approach ensures that all relevant aspects of digitalization are captured. Unlike surveys, we construct this measure using administrative data, implying that there are no issues with overrepresentation of sectors and firm types that are more likely to invest in digitalization. The estimated results therefore provide a better estimate of the economy-wide effects of digitalization. However, there are limitations to our approach as well. Firm-to-firm trade data provide little information about the content of purchases. Simply spending money does not guarantee effective integration of digitalization. Furthermore, the index excludes imported digital goods and services as well as in-house technological development due to data constraints.

Finally, the independence of digitalization from firm characteristics commonly associated with resilience to shocks, such as size, age, sales, exports, leverage and liquidity is important for measuring its role in firm performance. If the digitalization index is strongly correlated with these variables in pre-pandemic period, it will be difficult to disentangle the effects of digitalization from those of firm resilience. As shown in Table 3, the correlations are consistently low, suggesting that the index captures a distinct dimension of firm behavior. Therefore, the digitalization index is not a proxy for firm resilience, but reflects an independent indicator of firm's engagement in digital technologies.

Table 3: Correlation between Digitalization Index and Firm Characteristics

| | 2018 | 2019 |
|---|---|---|
| Total Assets | 0.015 | 0.019 |
| Net Sales | 0.024 | 0.029 |
| Debt | 0.011 | 0.014 |
| Employment | -0.009 | -0.006 |
| Profitability | 0.005 | 0.003 |
| Age | -0.003 | -0.003 |
| Export Share | -0.004 | -0.004 |
| Leverage | -0.003 | -0.002 |
| Current Ratio | 0.002 | -0.001 |
| Cash Ratio | 0.006 | -0.001 |
| Observations | 541,562 | 541,562 |

*Notes: This table presents the correlation between digitalization index and various firm characteristics in 2018 and 2019. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees and export share is calculated as export sales over total gross sales. Firm age is calculated by subtracting the year of establishment from the current year. Leverage indicates total debt to asset ratio, current ratio is current assets over short term liabilities, cash ratio is liquid assets and marketable securities over short term liabilities.*

# 4 Empirical Strategy

In this study, we employ a DID approach to estimate the impact of digitalization on firm performance. The COVID-19 pandemic serves as a genuine exogenous shock in this framework, providing a unique opportunity to examine the causal effects of digitalization. During the pandemic, digital transformation played a key role in helping firms adapt and respond effectively to the crisis. By leveraging this natural experiment, we can better understand how digitalization influences firm performance under downturns. To implement this approach, we first categorize firms into two groups: treated firms, which are more digitalized, and control firms, which are less digitalized. We then apply a matching process to pair treated firms with similar control firms based on key pre-pandemic characteristics. This matching ensures that the comparison between the two groups is fair and that any observed differences in performance can be attributed to digitalization rather than other factors.

## 4.1 Establishing Treated and Control Groups and Matching

We categorize firms into treated and control firms based on the digitalization index that we have constructed. This index is defined as the average purchases of digital products and services per employee during the pre-pandemic period (2015-2019). By using this index, we can identify the degree of digitalization for each firm prior to the pandemic. Our analysis focuses exclusively on the subsample of firms that continued to operate during 2020 or 2021, allowing us to specifically examine the impact of digitalization on firm performance during and after the pandemic. By narrowing our focus on these firms, we can better understand how pre-existing digital capabilities influenced their ability to navigate the challenges posed by COVID-19.

The treated group consists of firms with a digitalization index above the 2-digit sector–specific median, indicating a higher degree of digitalization. Conversely, the control group comprises firms with a digitalization index below the sectoral median, indicating lower degrees of digitalization. After labeling all firms, we implement one-to-one matching between treated and control firms using CEM without replacement. This matching process ensures that each treated firm is paired with a control firm that has similar characteristics in the same sector. Matching is based on standard firm characteristics: sector, age, total assets, net sales, export share[6] and number of employees in 2018 and 2019. Total assets, net sales and employment are coarsened after log-transformation, whereas age and export share are coarsened in levels. The matching is conducted within 2-digit sector level to avoid sector specific digitalization performance affecting the construction of groups. Otherwise, dominance of technology-intensive sectors in the top percentiles could bias the results. We employ Stata's default cut-point selection algorithm based on Sturges' Rule.[7] After CEM, any bin that is missing either treated or control firms is dropped.

The descriptive statistics for these variables before and after the matching are presented in Tables 4 and 5. The differences between the means of firms characteristics are reduced significantly after the matching procedure, indicating that the treated and control groups are well-balanced and comparable.

Table 4: Matching Performance: Group Means

| | Unmatched Sample | | | | Matched Sample | | | |
|---|---|---|---|---|---|---|---|---|
| | 2018 | | 2019 | | 2018 | | 2019 | |
| | Treated | Control | Treated | Control | Treated | Control | Treated | Control |
| Total Assets | 9.00 | 7.75 | 8.85 | 7.61 | 8.11 | 8.11 | 7.96 | 7.95 |
| Net Sales | 8.95 | 7.51 | 8.76 | 7.33 | 8.20 | 8.16 | 7.97 | 7.94 |
| Employment | 0.81 | 0.45 | 0.75 | 0.39 | 0.52 | 0.52 | 0.47 | 0.47 |
| Export Share | 7.16 | 5.99 | 7.54 | 6.33 | 1.56 | 1.52 | 1.94 | 1.90 |
| Age | 11.95 | 9.11 | 11.77 | 8.81 | 9.33 | 9.27 | 9.04 | 8.99 |
| Observations | 481,566 | | 541,545 | | 121,498 | | 143,370 | |

*Notes: This table presents descriptive statistics across treated and control groups for the matched and unmatched sample for the year 2018 and 2019. The mean values in the table are annual averages. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees and export share is calculated as export sales over total gross sales. Firm age is calculated by subtracting the year of establishment from the current year.*

[6] Export share is in percentage points. We observe consistent qualitative outcomes when employing an export dummy variable instead of using export shares. This suggests that our results remain robust and are not significantly influenced by the choice of the export measure.

[7] We also implement alternative cut-point selection methods, including Scott's and Freedman–Diaconis rules. The results remain robust across specifications.

Table 5: Matching Performance: Balancing Tests

| | 2018 | 2019 |
|---|---|---|
| Total Assets | -0.002 | -0.002 |
| Net Sales | -0.032*** | -0.029*** |
| Employment | -0.003 | -0.005 |
| Age | -0.054 | -0.043 |
| Export share | -0.039 | -0.043 |
| Observations | 121,498 | 143,370 |

*Notes: This table presents balancing tests to evaluate matching performance. Balancing test compares the means of treated and untreated groups. The coefficients are the differences between treated and untreated means. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees and export share is calculated as export sales over total gross sales. Firm age is calculated by subtracting the year of establishment from the current year. Stars are for p values: *** p<0.01, ** p<0.05, * p<0.1.*

### 4.2 DID Analysis

We employ a DID model to estimate the impact of digitalization on firm performance using the matched sample. This model allows us to compare the changes in performance between firms with higher levels of digitalization (treated firms) and similar firms with lower levels of digitalization (control firms). We implement a 2-year time window around the treatment. The pre-COVID period includes 2018 and 2019 while the pandemic and post-pandemic period includes 2020 and 2021. The baseline estimation model is given by:

$$y_{it} = \beta_0 + \beta_2 treated_i * COVID_t + T_t * sector_i + f_i + \epsilon_{it} \quad (1)$$

where $i$ denotes firm and $t$ denotes year. $treated_i$ is a binary variable which takes the value one if firm $i$ belongs to the treated group (more digitalized firms before COVID-19), and zero otherwise. The variable $COVID_t$ takes the value one for the years 2020-2021 and zero for the years 2018-2019. $T_t$ is a year dummy and $sector_i$ is the 2-digit sector level fixed effects.[8] In order to control for year specific sector level shocks, we include sector-year fixed effects, $T_t * sector_i$. We also control for firm-level fixed effects, $f_i$.[9] $\epsilon_{it}$ is the error term. The errors are clustered at the firm level.

The dependent variable, $y_{it}$, denotes firm performance indicators: total assets, net sales, employment, profitability, return on assets and export share. The coefficient $\beta_3$ estimates the difference in firm performance between more digitalized and less digitalized firms.[10]

[8] Our estimates use 2-digit level sector fixed effects, and we find that the results closely align with those obtained using 4-digit level sector fixed effects. We prefer to proceed with the 2-digit levels in order to maximize the number of matched firms.

[9] The inclusion of firm level fixed effects $f_i$ controls for all time invariant characteristics of each firm. Since $treated_i$ is constant over time, it becomes perfectly collinear with the firm fixed effects. Similarly, $COVID_t$ is collinear with $T_t * sector_i$ which controls for sector-specific shocks varying over time. So, $treated_i$ and $COVID_t$ are dropped to avoid multicollinearity.

[10] We validate the parallel trends assumption for the specified firm performance indicators by conducting an event

# 5 Results

In this section, we present the estimation results of the DID analysis, which examines the impact of digitalization on various firm performance indicators, including total assets, net sales, employment, profitability, return on assets and export share. Digitalization can affect these variables, each of them reflecting different dimension of firm performance. For example, sales measure the ability to generate revenue, while profitability indicates how efficiently a firm converts sales into profit. Digitalization can improve this by reducing costs and optimizing production processes. Return on assets captures how effectively a firm uses its assets to generate profit, with digitalization improving asset utilization through better management and coordination. Export share is an important indicator of engagement in digitalization because digital tools like e-commerce reduce the cost of entering foreign markets, increasing the share of exports in sales. By examining these indicators, we can get a comprehensive assessment of the effects of digitalization across multiple dimensions of firm performance.

We begin with presenting the baseline estimations and time-varying effects of digitalization on these performance indicators. This initial analysis provides a broad overview of how digitalization has influenced firm performance over the pandemic and post-pandemic period. We then provide a more detailed analysis by categorizing firms according to size (micro, small, medium-sized and large) to determine if the impact of digitalization varies with firm size. This breakdown provides insights into the heterogeneous effectiveness of digital investments across different firm sizes.

## 5.1 Main Results

In this section, we present the findings of our baseline DID analysis. The estimation results of Equation 1 are presented in Table 6. The results reveal that firms with higher levels of digitalization have shown statistically significant improvements across several key performance indicators relative to their less digitalized pairs in the pandemic and post-pandemic period. Specifically, more digitalized firms exhibit total assets, net sales, and employment levels that are approximately 3%, 4%, and 2% higher, respectively. The impact of digitalization is even more pronounced in terms of profitability, return on assets, and export share, with levels ranging from 0.16 to 0.44 percentage points higher. All the coefficients are statistically significant. The findings highlight the critical role of digital investments in supporting firm resilience and growth during economic downturns.

study using the data from 2018 to 2021 in Section 7.

Table 6: The Effect of Digitalization on Firm Performance

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*COVID | 0.03*** | 0.04*** | 0.02*** | 0.44*** | 0.42*** | 0.16*** |
| | (0.00) | (0.01) | (0.00) | (0.09) | (0.09) | (0.03) |
| Constant | 8.09*** | 8.03*** | 1.43*** | 1.27*** | 3.49*** | 2.09*** |
| | (0.00) | (0.00) | (0.00) | (0.02) | (0.02) | (0.01) |
| Observations | 537,285 | 529,171 | 539,699 | 490,096 | 489,794 | 529,015 |
| R-squared | 0.91 | 0.83 | 0.90 | 0.58 | 0.62 | 0.91 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table shows the regression results from Equation 1, examining the effect of digitalization on firm performance. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Realizing the full benefits of investments in digitalization is a gradual process due to several factors. The implementation of new technologies and processes takes time for installation, integration, and training. Employees and management need time to adapt to these changes, referred to as a learning curve. As users of digital tools build up more experience, the tools become more effective and easier to utilize. To capture the evolving effects over time, our approach involves incorporating interactions between treated firms and individual years separately in the DID analysis as specified in Equation 2 .

$$y_{it} = \beta_0 + \beta_1 treated_i + \beta_2 2020_t + \beta_3 2021_t + \beta_4 treated_i * 2020_t + \beta_5 treated_i * 2021_t + T_t * sector_i + f_i + \epsilon_{it} \quad (2)$$

This approach allows us to observe how the impact of digitalization varies over time. The estimates of the time-varying effects of digitalization are displayed in Table 7. The results indicate that more digitalized firms consistently outperform their less digitalized pairs in pandemic (2020) and post-pandemic years (2021). The estimated effects are larger in 2021 across all the performance indicators excluding profitability. This suggests that the benefits of digital investments are not only immediate but also persistent, becoming more pronounced over time as firms move along the learning curve.

Table 7: The Time Varying Effect of Digitalization on Firm Performance

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*2020 | 0.02*** | 0.04*** | 0.02*** | 0.55*** | 0.37*** | 0.13*** |
| | (0.00) | (0.01) | (0.00) | (0.10) | (0.10) | (0.03) |
| Treated*2021 | 0.03*** | 0.05*** | 0.03*** | 0.33*** | 0.47*** | 0.19*** |
| | (0.00) | (0.01) | (0.00) | (0.11) | (0.11) | (0.04) |
| Constant | 8.09*** | 8.03*** | 1.43*** | 1.27*** | 3.49*** | 2.09*** |
| | (0.00) | (0.00) | (0.00) | (0.02) | (0.02) | (0.01) |
| Observations | 537,285 | 529,171 | 539,699 | 490,096 | 489,794 | 529,015 |
| R-squared | 0.91 | 0.83 | 0.90 | 0.58 | 0.62 | 0.91 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table shows the regression results from Equation 2, examining the effect of digitalization on firm performance by explicitly interacting the year 2020 and year 2021 dummies with the Treated dummy to see the time varying effects. The main coefficients of interest, Treated*2020 and Treated*2021 are presented. Coefficients of other variables are not shown here for brevity. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

### 5.2 Estimation Results by Size

In this part, we check whether the effects of digitalization vary by firm size. The impact may differ across firms due to a number of key factors. Several studies emphasize that larger firms are more likely to engage in digital adoption due to greater access to capital, skilled labor, and advanced IT infrastructure, which enhances their ability to integrate complex digital systems (e.g., Bessen, 2019; Bughin et al., 2019). However, larger firms may also face greater coordination and integration challenges due to their more rigid organizational structures, which can slow down the realization of productivity gains (Brynjolfsson and Hitt, 2000; Billi and Bernardo, 2025). In contrast, smaller firms, while constrained by limited financial and human capital resources (Li et al., 2018), tend to be more agile and adaptive, enabling quicker implementation of digital tools, especially cloud-based and off-the-shelf solutions (DeStefano et al., 2020; Andrews et al., 2018). This adaptability may allow smaller firms to realize relatively rapid improvements in performance and market expansion, particularly when digital tools are used to overcome scale and geographic limitations (OECD, 2021; Costa and Castro, 2021). However, their limited internal capacity may also increase vulnerability to transition costs and digital disruptions.

To conduct the analysis, we classify firms into three categories by size: micro, small, and medium and large firms. Firm size is based on the official KOSGEB definition.[11] Micro firms have fewer than 10 employees. Small firms have 10 to 49 employees. Medium firms have 50 to 249 employees. Large firms have more than or equal to 250 employees. We combine medium-

[11] KOSGEB, which is the Turkish acronym for Small and Medium Enterprises Development Organization, is a public institution that serves the purpose of providing development space for SMEs in Türkiye and increasing the competitiveness of enterprises.

sized and large firms into a single category to increase the number of observations. Estimation results of Equation 1 across these size groups are provided in Table 8. The findings reveal that more digitalized micro and small firms exhibit significantly higher total assets, net sales and employment, by between 2% and 5%, compared to their less digitalized pairs in the pandemic and post-pandemic period.

Treated micro and small firms record 0.48 and 0.36 percentage points higher profitability than their control pairs, respectively. More digitalized micro firms display 0.50 percentage points higher increase in return on assets than their less digitalized pairs, while this impact is 0.23 percentage points for small firms but insignificant. The treated micro and small firms display 0.18 and 0.11 percentage points higher increase in export share, respectively. For medium and large firms, the coefficients are generally larger in magnitude; however, they are often statistically insignificant. This might be due to the smaller sample size. Further investigation is warranted to fully understand the heterogeneity of impact across size groups. This variation may be due to differences in resource availability, organizational structure, adaptability, and market dynamics, as mentioned above.

Table 8: The Effect of Digitalization on Firm Performance by Size

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Panel A: Micro Firms | | | | | | |
| Treated*COVID | 0.02*** | 0.05*** | 0.02*** | 0.48*** | 0.50*** | 0.18*** |
| | (0.00) | (0.01) | (0.00) | (0.11) | (0.11) | (0.04) |
| Constant | 7.64*** | 7.50*** | 1.00*** | 1.34*** | 3.49*** | 1.85*** |
| | (0.00) | (0.00) | (0.00) | (0.03) | (0.03) | (0.01) |
| Observations | 373,738 | 366,483 | 375,753 | 332,635 | 332,348 | 366,044 |
| R-squared | 0.86 | 0.76 | 0.82 | 0.58 | 0.63 | 0.88 |
| Panel B: Small Firms | | | | | | |
| Treated*COVID | 0.03*** | 0.03*** | 0.03*** | 0.36** | 0.23 | 0.11*** |
| | (0.01) | (0.01) | (0.01) | (0.15) | (0.15) | (0.04) |
| Constant | 9.08*** | 9.18*** | 2.36*** | 1.13*** | 3.46*** | 2.56*** |
| | (0.00) | (0.00) | (0.00) | (0.04) | (0.04) | (0.01) |
| Observations | 156,963 | 156,136 | 157,087 | 150,925 | 150,907 | 156,150 |
| R-squared | 0.90 | 0.80 | 0.85 | 0.58 | 0.62 | 0.96 |
| Panel C: Medium and Large Firms | | | | | | |
| Treated*COVID | 0.02 | 0.06* | 0.07** | 0.58 | 0.86 | -0.04 |
| | (0.03) | (0.04) | (0.03) | (0.69) | (0.72) | (0.16) |
| Constant | 10.06*** | 10.36*** | 3.88*** | 1.35*** | 4.01*** | 4.70*** |
| | (0.01) | (0.01) | (0.01) | (0.18) | (0.19) | (0.04) |
| Observations | 6,566 | 6,533 | 6,841 | 6,516 | 6,519 | 6,802 |
| R-squared | 0.94 | 0.83 | 0.93 | 0.62 | 0.65 | 0.99 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table presents the regression results from Equation 1, examining the effect of digitalization on firm performance by firm size groups. Panel A, B and C provide results for micro firms, small firms, and medium and large firms respectively. Firm size is based on the official KOSGEB definition. Micro firms have less than 10 employees. Small firms have 10 to 49 employees. Medium firms have 50 to 249 employees. Large firms have more than or equal to 250 employees. The main coefficient of interest, Treated*COVID is presented. Coefficients of other variables are not shown here for brevity. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

# 6 Potential Channels: How Digitalization Improves Firm Performance

Digitalization can improve firm performance by strengthening resilience and flexibility, allowing firms to respond more effectively to changing market conditions and economic shocks such as COVID-19. Understanding the mechanisms through which digitalization affects firm performance is important to leverage its potential. In this section, we focus on three key channels: (i) trade network expansion, (ii) labor market adjustment, and (iii) productivity. These channels

were selected based on both theoretical relevance and data availability.[12] The first two are relevant to highlight in our context because we are studying the pandemic years during which labor turnover and supply chains were particularly important for firm survival. The third channel, productivity, is a more general measure of performance and may actually be affected through many other mechanisms including financial services and cost-saving in the production mix, and process innovation.

The first channel we explore is the expansion of trade networks. To the best of our knowledge, we are the first to examine this mechanism in the context of digitalization during the pandemic. Digital technologies can reduce transaction and coordination costs, facilitating more efficient communication with suppliers and customers. This, in turn, enables firms to expand their market reach and maintain operations despite physical restrictions. The second channel relates to labor market dynamics. Digitalized firms were better able to adopt remote working arrangements during the pandemic, which supports business continuity and enhancing worker satisfaction and productivity (Strandt, 2024). Digital tools may also reduce labor churn by improving job flexibility. Finally, productivity captures the cumulative effects of digitalization. Existing literature has shown that digitalization supports both product and process innovation and promotes long-term productivity growth (Andrews et al., 2016; Cette et al., 2022; Gal et al., 2019). By adopting information and communication technologies, firms can reorganize production, management, and communication processes more effectively and so can achieve higher productivity levels. Conversely, firms that delay digital adoption risk being left behind. In our context, the observed improvements in trade networks and labor market stability are likely to contribute to these productivity gains. We now turn to each of these mechanisms in detail.

### 6.1 Trade Networks

One plausible mechanism for the superior performance of more digitalized firms following a shock like COVID-19 is that digitalization may enable better coordination and integration of trade activities. Automation and digital tools can reduce the costs associated with managing trade relationships, allowing firms to reach a broader range of trade partners. Additionally, digitalization may improve a firm's adaptability to market changes and economic shocks, and so maintain stable trade networks even in challenging times. To explore this hypothesis, we conduct a DID analysis on trade partners engaged in sales using the matched sample. Using the firm-to-firm trade dataset spanning the 2018-2021 period, we calculate two indicators related to firms' trade networks for each year. This analysis allows us to assess how digitalization has influenced the dynamics of trade relationships and contributed to the resilience and adaptability of firms during economic disruptions.

[12] While we acknowledge that digitalization may also influence firm outcomes through other pathways (e.g. process innovation, access to finance), our administrative data do not allow us to observe these dimensions directly. We should note that some of these omitted mechanisms may be partially captured through our productivity measures. Our aim is to provide reduced-form evidence on plausible mechanisms, grounded in theory and supported by the available data, rather than to model the full causal structure linking digitalization to firm performance.

We distinguish between two key margins of trade network adjustment. First, for each year and firm, we compute the logarithm of the number of trading partners to whom a sale is made, *Number of partners*. The second indicator, *Distance*, is the logarithm of the sales-weighted average of the distances between all trading partners of the firm. The distance between two trading partners is defined as the distance in kilometers between the cities where their headquarters are located. *Distance* is weighted by the sales volume associated with each trading partner. These indicators allow us to examine the potential impact of digitalization on trade network expansion in the shock period. The first is the extensive margin, captured by the number of trading partners. The second is the geographic diversification margin, measured by the average distance to trade partners.

Panel A of Table 9 shows the DID estimation results of Equation 1.[13] The number of trading partners of more digitalized firms is increased by 3% higher than their less digitalized pairs. This indicates that digitalization helped firms to connect with a larger number of partners, likely because digital tools made it easier to find and coordinate with new buyers and suppliers by reducing search and coordination costs. The weighted average distances of trade partners for the treated group increase by 2% more than the control group. The rise in distance suggests a greater ability to engage with geographically distant partners, reflecting improved logistical flexibility and digital connectivity. These results suggest that digitalization helped firms overcome both physical and informational barriers during the pandemic and post-pandemic years.

[13] We validate the parallel trends assumption for the specified trade indicators by conducting an event study using the data from 2018 to 2021.

Table 9: The Effect of Digitalization on Trade Networks

| Variables | (1) Number of partners | (2) Distance |
|---|---|---|
| Panel A: Baseline Estimation | | |
| Treated*COVID | 0.03*** | 0.02*** |
| | (0.00) | (0.01) |
| Constant | 2.31*** | 3.62*** |
| | (0.00) | (0.00) |
| Observations | 462,724 | 462,724 |
| R-squared | 0.88 | 0.75 |
| Panel B: Time-Varying Effects | | |
| Treated*2020 | 0.04*** | 0.02** |
| | (0.00) | (0.01) |
| Treated*2021 | 0.03*** | 0.02** |
| | (0.01) | (0.01) |
| Constant | 2.31*** | 3.62*** |
| | (0.00) | (0.00) |
| Observations | 462,724 | 462,724 |
| R-squared | 0.88 | 0.75 |
| Firm FE | Yes | Yes |
| Sector*Year FE | Yes | Yes |

*Notes: Panel A of the table shows the regression results from Equation 1, examining the effect of digitalization on the performance of firms in terms of trade networks. Panel B indicates the results from Equation 2, examining the effect of digitalization on the performance of firms in terms of trade networks by explicitly interacting the year 2020 and year 2021 dummies with Treated dummy to see the time varying effects. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. Number of partners is the logarithm of the number of trading partners to whom a sale is made in a given year. Distance is the logarithm of the sales-weighted average distance between all trading partners of a firm. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

The estimates of the time-varying effects of digitalization on trade networks are displayed in Panel B of Table 9. More digitalized firms demonstrate significantly better performance than their less digitalized pairs in both years. The coefficients are similar for pandemic and post-pandemic years. This section therefore verifies the earlier findings which highlight the continuing and long-lasting effects of digital investment.

### 6.2 Labor Market

Advances in information technologies have driven rapid digital transformation, and COVID-19 has further accelerated this transformation, reshaping the work environment and the workplace. Digitalized firms were better able to adopt remote working arrangements during the pandemic, which supports business continuity and enhancing worker satisfaction and productivity (Strandt, 2024). Digitalization can lead to both job creation and job displacement. On the one hand, it can create new types of jobs and skill requirements. On the other hand, it may adversely affect some manual or routine jobs. The literature also provides mixed results on the impact of digitalization

on employment levels (see David, 1990, Brynjolfsson and McAfee, 2014). In the short term, digitalized firms can be expected to increase the number of jobs available. However, in the longer term, the number of jobs in digitalized firms may decrease due to the substitution of labor by automation. Our baseline results in Table 6 show that digitalization is associated with higher employment. Moreover, digital platforms can make it easier to find the right talent by reducing costs and time which can increase the number of new hires. The impact of digitalization on churn rates varies. While automation might displace low-skill jobs, a flexible working environment can reduce the churn rate by increasing job satisfaction and productivity. The relationship between digitalization and salaries is similarly multifaceted. On the one hand, digitalized firms often see increased productivity, which can lead to higher salaries, particularly for high-skill workers who can effectively leverage digital tools and technologies. On the other hand, automation and digital tools may put downward pressure on salaries for roles that can be substituted by technology, particularly in routine and manual job categories.

We now take a closer look at the labor market dynamics using granular data at the employee-firm level in Table 10. The estimated results show that the mean salary remains unchanged, indicating that digitalization does not significantly affect salaries. This finding aligns with the work of Card and DiNardo (2002), who found that technological changes do not always translate to wage increases. Another important factor, specific to Türkiye, could be that the majority of employees work at the minimum wage which is set by the government. Additionally, employers generally have a high power in wage setting. As such, the benefits from digitalization may not be reflected in the salaries.

The relationship between digitalization and employee turnover is complex. Digitalization can lead to job displacement due to automation. However, particularly during the pandemic, it can enhance employee engagement and retention through improved work environments and job satisfaction. The churn rate of more digitalized firms decreased by 0.61 percentage points more compared to their less digitalized pairs. Our results suggest that more digitalized firms had lower employee turnover in pandemic and post-pandemic years. Consistent with this finding, more digitalized firms recorded 0.81 percentage points increase in new hires rate and 0.94 percentage points reduction in separations rate relative to their less digitalized pairs.

Overall, our analysis demonstrates that while digitalization does not impact salaries, it does lead to a more stable workforce with lower employee turnover, contributing to higher employment levels. These results point to efficiency gains in the labor market matching processes of digitalized firms. Vacancy filling likely becomes cheaper since digitalization allows for remote work, lessening the impact of physical mobility restrictions imposed by the pandemic conditions.

Table 10: The Effect of Digitalization on Labor Market

| Variables | (1) Mean Salary | (2) Churn Rate | (3) New Hires Rate | (4) Separations Rate |
|---|---|---|---|---|
| Treated*COVID | -0.00 | -0.61** | 0.81* | -0.94*** |
| | (0.00) | (0.30) | (0.48) | (0.32) |
| Constant | 1.80*** | 52.00*** | 33.76*** | 29.88*** |
| | (0.00) | (0.08) | (0.12) | (0.08) |
| Observations | 374,058 | 352,934 | 352,934 | 352,934 |
| R-squared | 0.85 | 0.48 | 0.46 | 0.44 |
| Firm FE | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes |

*Notes: The table shows the regression results from Equation 1, examining the effect of digitalization on the firm level variables regarding labor market. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. Mean salary is deflated by CPI. Churn rate is defined as the sum of new hires and separations as a proportion of the total number of employees. New hires rate is the number of new hires as a proportion of total number of employees. Separations rate is the number of separations as a proportion of total number of employees. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

### 6.3 Productivity

Given the effects on trade networks and employee retention, it is natural to expect that digitalization could be associated with higher firm productivity. A growing body of empirical research investigates the relationship between digitalization and productivity. Evidence suggests that digitalization supports both product and process innovation and promotes long-term productivity growth (Andrews et al., 2016; Cette et al., 2022; Gal et al., 2019). Brynjolfsson and McAfee (2014) emphasize digitalization has the potential to generate exponential improvements in productivity, much like the steam engine and electricity did in earlier eras. However, it often requires time and institutional adaptation which can lead to a delayed productivity response. Tambe and Hitt (2012) provide evidence that information technologies related labor plays a crucial role in realizing the returns to digital investments, as firms with more skilled technology workforces experience higher productivity. Similarly, Bresnahan et al. (2002) show that productivity gains from information technologies are strongest when paired with complementary organizational changes. Bloom et al. (2012) demonstrate that superior management practices amplify the benefits of information technologies adoption, explaining cross-country productivity differences. This heterogeneity is further documented in Andrews et al. (2019), which shows that digitalization has led to growing dispersion in firm-level productivity, with only frontier firms capturing the majority of gains.

We test whether digitalization boosts productivity by using basic measures of firm productivity defined as sales per employee and sales over assets. As shown in columns (1) and (2) of Table 11, digitalized firms have greater productivity levels in the pandemic and post-pandemic period. Columns (3) and (4) use an alternative categorical approach, placing firms into deciles based on their sales per employee and sales over assets at the 2-digit sector-year level and estimating an ordered probit version of Equation 1. The results show that digitalized firms are more

likely to move to a higher productivity group, as indicated by the significant positive coefficients for the Treated*COVID interaction (0.02 for both variables). This suggests that digitalization not only enhances productivity in absolute terms but also improves the relative position of firms within their industries, supporting the view that digitalization improves competitive advantage (as in Porter (1985)).

In summary, our analysis reveals that digitalization boosted relative productivity during the pandemic. These results are in line with the more general view that digital technologies can significantly enhance firm performance and competitiveness. Our results confirm the findings of Brynjolfsson and McAfee (2014) and Tambe and Hitt (2012) which show that digitalization can lead to significant productivity gains. Brynjolfsson and McAfee (2014) demonstrate full impact on productivity is uneven and delayed due to institutional and measurement lags. In our case, we observe the productivity effects even within a year.

Table 11: The Effect of Digitalization on Productivity

| | OLS | | Ordered Probit | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Variables | Sales / Emp. | Sales / Assets | Sales / Emp. (ranking) | Sales / Assets (ranking) |
| Treated*COVID | 0.03*** | 0.01* | 0.02*** | 0.02*** |
| | (0.00) | (0.01) | (0.01) | (0.01) |
| Treated | | | 0.03*** | 0.03*** |
| | | | (0.00) | (0.00) |
| COVID | | | -0.08*** | -0.12*** |
| | | | (0.00) | (0.00) |
| Constant | 6.63*** | 1.50*** | | |
| | (0.00) | (0.00) | | |
| Observations | 490,635 | 495,797 | 494,039 | 498,763 |
| R-squared | 0.84 | 0.76 | | |
| Firm FE | Yes | Yes | | |
| Sector*Year FE | Yes | Yes | | |

*Notes: The first two columns of the table show the regression results of 1 for the effect of digitalization on the firm productivity. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. Productivity is defined as sales per employee or total sales over assets. In the last two columns, we build categorical variables, placing firms into deciles based on their sales per employee and sales over assets at the 2-digit sector-year level respectively to run ordered probit regressions. Firm fixed effects together with sector*year fixed effects are included for the first and second regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

## 7 Robustness Checks

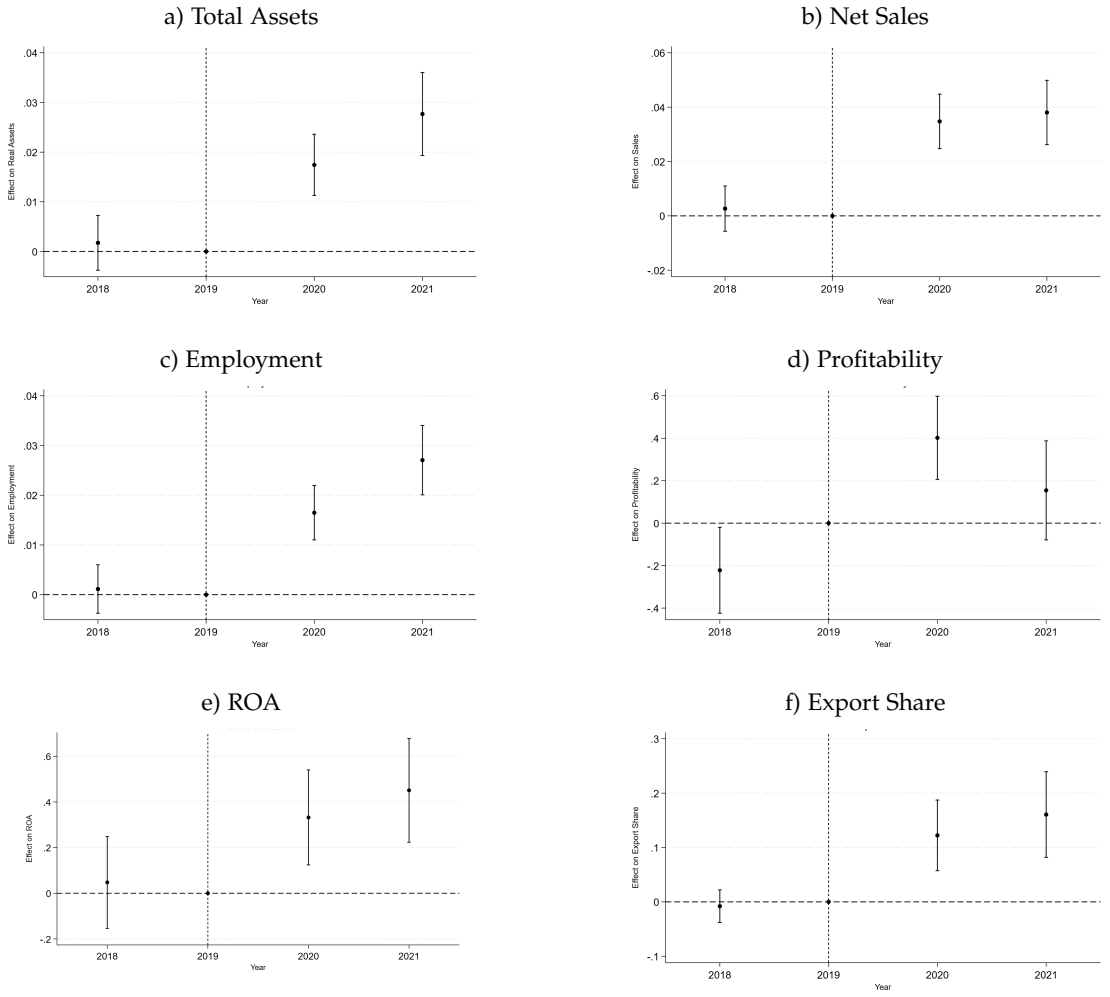
This section aims to validate the robustness of our results through placebo tests and a different subsample. We first validate the parallel trend assumption and conduct a placebo test which repeats the DID analysis on the same matched sample, setting the treatment time two years prior to the pandemic shock. Second, we employ a different sample which excludes the firms with zero digital purchases and builds alternative digitalization indices. Finally, we present a range of additional robustness checks.

### 7.1 Identification Strategy: Event-Study and Placebo Tests

This section assesses the validity of the identification strategy underlying the DID framework. We examine the parallel trends assumption using an event-study design and complement this analysis with placebo tests.

In order to verify the key parallel trends assumption underlying our DID analysis, we conduct an event study that incorporates year-by-treatment interaction terms for 2018-2021 period. This event study examines potential pre-treatment differences in trends between the treatment and control groups. As illustrated in Figure 3, the estimated coefficients for the pre-treatment interaction terms (2018 and 2019) are small and statistically insignificant, and we fail to reject their joint significance. These results reveal no evidence of divergent trends in the pre-treatment years, indicating that the treated and control groups followed parallel trends in the explanatory variables prior to the pandemic. The divergence between the two groups begins in 2020. This approach strengthens the validity of our findings by ensuring that the observed effects are due to digitalization rather than pre-existing differences between the firms.

Figure 3: Event Study Estimations




*Notes: The figure reports coefficients from the event-study specification that incorporates year-by-treatment interaction terms for 2018-2021 period. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions.*

As a placebo test, we change the treatment timing in our baseline setup. This approach allows us to assess whether the baseline effects would have been seen in the absence of the pandemic. We set the treatment time two years prior to the onset of COVID-19. On the same matched sample, we run the identical DID analyses in Equation 1, designating 2016-2017 as the pre-treatment period and 2018-2019 as the post-treatment period. The results presented in Table 12 show no significant positive effect on any of the firm performance indicators under this modified intervention period.[14]

[14] Similarly, there is no significant expected impact on trade networks, labor market, or productivity in placebo tests.

Table 12: Placebo Tests: The Effect of Digitalization on Firm Performance

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*COVID | -0.02*** | -0.05*** | -0.01*** | -0.21** | -0.19** | -0.06** |
| | (0.00) | (0.01) | (0.00) | (0.09) | (0.09) | (0.03) |
| Constant | 8.13*** | 8.15*** | 1.51*** | 1.67*** | 3.86*** | 1.64*** |
| | (0.00) | (0.00) | (0.00) | (0.03) | (0.03) | (0.01) |
| Observations | 452,660 | 445,745 | 453,956 | 392,035 | 391,761 | 445,680 |
| R-squared | 0.91 | 0.83 | 0.90 | 0.58 | 0.62 | 0.94 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table repeats the regression set presented in Table 6. We set the intervention time to be 2 years prior to the onset of COVID-19. On the same matched sample, we run the identical DID analyses, designating 2016-2017 as the pre-treatment period and 2018-2019 as the post-treatment period. The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

### 7.2 DID Results with Alternative Digitalization Measures

Upon examining the entire sample, it becomes apparent that 55.8% comprises firms with zero digitalization. In our baseline specification, treatment is defined using a binary median split of the digitalization index. While this approach offers a straightforward comparison, we acknowledge its limitations given the skewed distribution of the index and the substantial mass of firms with zero digital purchases. These firms constitute a substantial portion of the control group in the initial specification. In an alternative specification, to test whether the effect is observable when variation is due to the intensity of digitalization, we exclude firms with a zero index value from the sample.[15] Within this refined sample, which exclusively contains firms with positive digitalization, we divide them into three percentiles based on their digitalization index values. Here, the treated group is constituted by firms in the top 33% (frontiers), characterized by the highest digitalization index values, while the control group comprises firms in the bottom 33% (laggards), reflecting the lowest digitalization index values. In this sample, we run the identical CEM algorithm according to the previously discussed firm characteristics including sectors, total assets, net sales, export share, employment and age in 2018 and 2019.

Panel A of Table 13 reports the DID estimation results. The most digitalized firms have their total assets and net sales higher by 2% compared to their less digitalized pairs in the pandemic period. We find no effect on employment. The impact is higher on profitability, return on assets and export share and ranges between 0.15 and 0.29 percentage points.[16]

To further explore the relationship between digitalization intensity and firm performance

[15] The mean and the standard deviation of the new digitalization index are 173.11 and 4035.10, respectively.

[16] In this new sample which excludes the firms with zero digitalization, main findings on the trade networks, labor market and productivity implications are preserved.

during pandemic and post-pandemic years, we conduct an additional robustness check comparing firms with zero digitalization to those in the top 33% percentile of the index. This specification helps us focus on the difference between firms that made no digital investments and those with the highest levels of digitalization. The results, presented in Panel B of Table 13, show even larger effects than in the previous comparison of top and bottom groups. This finding supports the idea that the benefits of digitalization are mainly observed in firms that have made significant investments, and that the baseline results may underestimate the true impact by including firms with little or no digital activity.

One concern is that our digitalization measure may hide the fact that technology investments are often characterized by infrequent investment spikes rather than spreading it evenly over time as shown by Bessen et al. (2025). If a firm spends a large amount on digitalization in one year and zero in other years, our averaging method smooths this out, treating it equally with a firm that spreads the same total investment evenly across several years. This raises the question of whether simply averaging expenditures over time accurately reflects a firm's adoption level. To address this concern, we conducted a robustness analysis on a restricted sample that limits the influence of such lumpy digitalization investments. In particular, we excluded all firms with no digital expenditure and those with only a single year of positive digitalization purchase. This treatment focuses on firms with more consistent digitalization investment rather than one-off spikes.

The results of this robustness check, reported in Panel C of Table 13, are consistent with our baseline results. The estimated effects of digitalization on firm performance measured by total assets, net sales, profitability and return on assets remain significant and positive, consistent with our baseline results. We find no effect on employment and export share. Even after removing firms with lumpy digitalization investments, the significant positive relationship between digitalization and firm performance persists. This suggests that our main results are not driven by firms' occasional investment spikes. Instead, it shows that the benefits we attribute to digitalization are linked to consistent adoption of digital products and services.

Table 13: Robustness Checks with Alternative Digitalization Measures

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Panel A: Excluding Zero Digital Investments | | | | | | |
| Treated*COVID | 0.02*** | 0.02** | -0.01 | 0.28* | 0.29* | 0.15** |
| | (0.01) | (0.01) | (0.01) | (0.17) | (0.17) | (0.06) |
| Constant | 9.01*** | 9.06*** | 2.19*** | 2.36*** | 5.05*** | 1.33*** |
| | (0.00) | (0.00) | (0.00) | (0.04) | (0.04) | (0.01) |
| Observations | 99,114 | 98,652 | 100,064 | 97,550 | 97,523 | 99,590 |
| R-squared | 0.95 | 0.89 | 0.93 | 0.55 | 0.61 | 0.87 |
| Panel B: Comparison of Non-Digital and Top Digitalization Firms | | | | | | |
| Treated*COVID | 0.03*** | 0.05*** | 0.01*** | 0.43*** | 0.33** | 0.11** |
| | (0.01) | (0.01) | (0.00) | (0.14) | (0.14) | (0.05) |
| Constant | 7.90*** | 7.87*** | 1.13*** | 1.71*** | 4.08*** | 2.29*** |
| | (0.00) | (0.00) | (0.00) | (0.04) | (0.04) | (0.01) |
| Observations | 228,671 | 224,096 | 230,374 | 199,100 | 198,841 | 223,956 |
| R-squared | 0.90 | 0.83 | 0.88 | 0.60 | 0.65 | 0.90 |
| Panel C: Excluding Zero and Lumpy Digital Investments | | | | | | |
| Treated*COVID | 0.01*** | 0.03*** | 0.00 | 0.26* | 0.32** | -0.00 |
| | (0.00) | (0.01) | (0.00) | (0.14) | (0.14) | (0.05) |
| Constant | 8.90*** | 8.93*** | 2.12*** | 2.37*** | 5.26*** | 1.53*** |
| | (0.00) | (0.00) | (0.00) | (0.04) | (0.04) | (0.01) |
| Observations | 178,956 | 177,719 | 181,471 | 174,072 | 174,026 | 180,312 |
| R-squared | 0.95 | 0.90 | 0.94 | 0.55 | 0.60 | 0.89 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: This table repeats the regression set presented in Table 6. Panel A excludes firms with zero digitalization and compare the firms in the top and bottom percentiles of index. Panel B compares firms with zero digitalization to those in the top percentile of the index. Panel C constructs a new digitalization measure where we exclude firms with no digital expenditure and those with only a single year of positive digitalization purchase. The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

### 7.3 Other Robustness Checks

In this section, we assess the robustness of our baseline findings by conducting a series of additional analyses.

As the first robustness check, we re-estimate the DID model in Equation 1 by explicitly controlling for interactions between the treatment indicator and key firm-level covariates, including leverage, firm age, and liquidity to address potential concerns regarding the interaction between firm characteristics and the pandemic shock. As shown in Table A.2, the resulting estimates remain consistent with our main findings, both in terms of magnitude and statistical significance, which supports the validity of our results.

Carry-along trade can bias estimates of the impact of digitalization on firm performance by blurring the distinction between true digital transformation and sole trading activity. In practice, some firms may purchase digital goods solely to resell. Such firms might have high digital purchases without genuine digital adoption. As a robustness check against potential bias from carry-along trade, we re-estimate the baseline model excluding firms in NACE 46 sector (wholesale trade). Table A.3 presents the results of this estimation. The impact remains highly similar in magnitude and statistical significance to our baseline findings. This indicates that the estimated effects of digitalization are not driven by wholesale traders.

The construction of digitalization index is based on digital purchases made during the 2015–2019 period as this window captures more recent investments which are likely to influence firm performance during the pandemic and post-pandemic years. To ensure the robustness of our digitalization index, we construct an alternative digitalization index using an extended time window 2009-2019. It is worth noting that the earlier period of 2009–2014 coincides with the aftermath of the global financial crisis and a period of high macroeconomic volatility in Türkiye, which may have influenced investment behavior. As shown in Table A.4, the results with the new digitalization index employing the extended window remain highly consistent with our baseline estimates.

Lastly, we expand the pre-treatment period in our DID analysis to cover the full decade prior to the pandemic, comparing firm outcomes between 2009–2019 and 2020–2021. The results remain consistent with our baseline findings with a shorter time window (2018-2019 vs 2020-2021) (see Tables A.5, A.6, A.7, A.8).

## 8 Conclusion

This paper demonstrates that digitalization can serve as a significant buffer during economic shocks, such as those induced by the pandemic. The baseline DID estimations reveal that more digitalized firms have outperformed their less digitalized pairs across several key performance indicators, including total assets, net sales, employment, profitability, return on assets, and export shares in the pandemic and post-pandemic period. The time-varying effects further highlight that the impact of digital investments is both immediate and sustained over time. Additionally, the impact of digitalization varies by firm size.

One key channel through which digitalization may affect firm performance is the expansion of trade networks. Digital technologies may enable efficient communication and coordination with trade partners and allow firms to expand their trade networks both in scale and reach. Another important channel is the labor market. Digitalization has reshaped labor markets by enabling remote work, changing how businesses operate, leading to both job creation and job displacement. Consistent with this, more digitalized firms exhibit lower employee churn, driven by fewer separations, despite no significant change in mean salaries. The last channel we have explored is productivity. Our results show that more digitalized firms have higher productivity

levels in the pandemic and post-pandemic period and also improve their relative positions within their sectors. Our results are robust, confirmed through various robustness checks including placebo tests, alternative samples and alternative constructions of digitalization measure.

The findings of this paper highlight that digitalization will continue to play a key role in adapting to the "new normal" after the pandemic. Correctly identifying and understanding the outcomes of the digitalization process has significant implications for policymakers and business models. For instance, our results suggest that firms may benefit from appointing new senior executives, such as Chief Digital Officers, or incorporating new digital-focused roles into top management teams to navigate digital transformation effectively. This strategy can help firms stay resilient in an increasingly digital world.

Governments and international institutions, such as the World Bank, EBRD, and EIB, can offer targeted financial assistance to the real sector. These institutions can support firms with the potential to enhance productivity or social welfare. This support can take various forms, such as grants, subsidies, and low-interest loans. Additionally, governments can invest in infrastructure to provide high-speed internet and improved connectivity. Our findings could have significant implications in this regard. Financial assistance and infrastructure investments can lower the barriers to digital adoption for firms, which can lead to better firm performance. This approach not only increases innovation and growth at the firm level but also contributes to overall economic resilience and productivity.

Future research should explore the broader impact of digitalization on macroeconomic trends and industry life cycles. Such investigations can provide deeper insights into how digitalization reshapes competitive dynamics, labor markets, the evolution of industries over time, and economic resilience on a larger scale. Understanding these impacts will be essential for developing strategies that maximize the benefits of digitalization while minimizing potential drawbacks. Future work could also incorporate the role of foreign firms which are important for technology transfer and digital diffusion in emerging markets. Including cross-border transactions and multinational activity would offer a more complete picture of the impact of digitalization and its transmission channels.

In conclusion, this paper highlights the transformative potential of digitalization in improving firm performance and economic resilience. As digital technologies continue to develop, their strategic implementation will be important for firms operating in an increasingly digitalized world. Digitally transformed firms will be better equipped to adapt to changing market conditions and economic shocks. Policymakers must prioritize digital investments and create supportive environments that encourage digital adoption for sustained growth, resilience, and competitiveness. Utilizing the full potential of digitalization will be essential for achieving long-term success in the digital age.

# A Appendix

## A.1 Variable List

Table A.1: Variable Definitions

| Variables | Definition | Source |
|---|---|---|
| Age | Time elapsed since the firm's establishment date | Firm Tax Registry |
| Cash Ratio | Sum of liquid assets and marketable securities over short term liabilities | Firm Tax Registry |
| Churn Rate | Sum of new hires and leavers as a proportion of the average total number of employees | Social Security Institution |
| Current Ratio | Current assets over short term liabilities | Firm Tax Registry |
| Debt | Log of deflated total debt by CPI | Firm Tax Registry |
| Distance | Log of the weighted average distance between all trading partners of a firm. The distance is defined as the distance in kilometers between the cities where the firms' headquarters are located. The sales volume associated with each trading partner are used as weights. | Revenue Administration |
| Employment | Log of total number of employees | Social Security Institution |
| Export Share | Export sales divided by gross sales (in percentage points) | Firm Tax Registry |
| Leverage | Total debt divided by total assets | Firm Tax Registry |
| Net Sales | Log of deflated net sales by CPI | Firm Tax Registry |
| Mean Salary | Log of the average of deflated salaries by CPI within a firm | Social Security Institution |
| New Hires Rate | Number of new hires in a firm as a proportion of the total number of employees | Social Security Institution |
| Number of Partners | Log of the number of trading partners to whom a sale is made | Revenue Administration |
| Return On Assets (ROA) | Operating income before depreciation divided by average total assets | Firm Tax Registry |
| Profitability | Net profits divided by average total assets | Firm Tax Registry |
| Purchase | Log of the amount of transaction due to a conducted Trade between firms | Revenue Administration |
| Sales/Assets | Total sales divided by average total assets | Firm Tax Registry |
| Sales/Assets (xtiles) | Categorical variable created by placing firms into deciles based on Sales/Assets ratio at the 2-digit sector level | Firm Tax Registry |
| Sales/Employment | Total sales divided by average number of employees | Firm Tax Registry |
| Sales/Employment (xtiles) | Categorical variable created by placing firms into deciles based on Sales/Employment ratio at the 2-digit sector level | Firm Tax Registry |
| Separations Rate | Number of employees who leave the firm as a proportion of the total number of employees | Social Security Institution |
| Total Assets | Log of deflated total assets by CPI | Firm Tax Registry |

## A.2 Other Robustness Check Results

Table A.2: Robustness: The Effect of Digitalization on Firm Performance (including Firm Characteristics)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variables | Total Assets | Net Sales | Employment | Profitability | ROA | Export Share |
| Treated*COVID | 0.03*** | 0.04*** | 0.02*** | 0.50*** | 0.47*** | 0.13*** |
| | (0.00) | (0.00) | (0.00) | (0.08) | (0.08) | (0.03) |
| Observations | 501,940 | 495,522 | 503,017 | 480,303 | 479,846 | 495,434 |
| R-squared | 0.93 | 0.86 | 0.91 | 0.65 | 0.67 | 0.92 |
| Firm Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector#Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 6 by explicitly controlling for firm characteristics including leverage, age and liquidity. The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.3: Robustness: Excluding Wholesalers (NACE46)

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*COVID | 0.03*** | 0.04*** | 0.02*** | 0.54*** | 0.43*** | 0.16*** |
| | (0.00) | (0.01) | (0.00) | (0.11) | (0.12) | (0.03) |
| Constant | 7.98*** | 7.86*** | 1.53*** | 0.81*** | 3.09*** | 0.84*** |
| | (0.00) | (0.00) | (0.00) | (0.03) | (0.03) | (0.01) |
| Observations | 401,572 | 394,766 | 403,330 | 365,206 | 364,980 | 394,412 |
| R-squared | 0.91 | 0.82 | 0.90 | 0.58 | 0.62 | 0.82 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector*Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 6 with excluding firms in NACE 46 sector (wholesale trade). The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.4: Robustness: New Digitalization Index with Extended Time Window (2009-2019)

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*COVID | 0.02*** | 0.03*** | 0.02*** | 0.57*** | 0.52*** | 0.15*** |
| | (0.00) | (0.01) | (0.00) | (0.09) | (0.09) | (0.03) |
| Constant | 8.02*** | 7.94*** | 1.37*** | 1.16*** | 3.28*** | 2.11*** |
| | (0.00) | (0.00) | (0.00) | (0.02) | (0.02) | (0.01) |
| Observations | 555,478 | 545,949 | 557,907 | 505,799 | 505,464 | 545,770 |
| R-squared | 0.91 | 0.83 | 0.90 | 0.57 | 0.62 | 0.92 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector#Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 6 with the new digitalization index based on digital purchases made between 2009 and 2019. The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.5: The Effect of Digitalization on Firm Performance with Expanded Window (2009-2021)

| Variables | (1) Total Assets | (2) Net Sales | (3) Employment | (4) Profitability | (5) ROA | (6) Export Share |
|---|---|---|---|---|---|---|
| Treated*COVID | 0.03*** | 0.03*** | 0.02*** | 0.23*** | 0.22*** | 0.09*** |
| | (0.00) | (0.01) | (0.00) | (0.08) | (0.08) | (0.03) |
| Constant | 8.09*** | 8.10*** | 1.51*** | 2.02*** | 4.22*** | 1.93*** |
| | (0.00) | (0.00) | (0.00) | (0.01) | (0.01) | (0.00) |
| Observations | 1,196,496 | 1,176,385 | 1,200,860 | 1,021,863 | 1,021,521 | 1,175,634 |
| R-squared | 0.81 | 0.70 | 0.79 | 0.43 | 0.48 | 0.84 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector#Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 6 with an expanded pre-treatment period covering 2009-2019. The main coefficient of interest is Treated*COVID. Each column presents a regression of column heading on the variables listed. All variables are deflated using the CPI. Total assets and net sales are in log levels. Employment is defined as the log of the total number of employees. Profitability is measured as net profits over total assets, return on assets is operating income before depreciation over total assets, export share is calculated as export sales over total gross sales. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.6: The Effect of Digitalization on Trade Networks with Expanded Window (2009-2021)

| Variables | (1) Number of Partners | (2) Distance |
|---|---|---|
| Treated*COVID | 0.03*** | 0.02** |
| | (0.00) | (0.01) |
| Constant | 2.29*** | 3.61*** |
| | (0.00) | (0.00) |
| Observations | 556,706 | 556,706 |
| R-squared | 0.86 | 0.72 |
| Sector#Year FE | Yes | Yes |
| Firm FE | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 9 with an expanded the pre-treatment period covering 2009-2019. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. Number of partners is the logarithm of the number of trading partners to whom a sale is made in a given year. Distance is the logarithm of the sales-weighted average distance between all trading partners of a firm. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.7: The Effect of Digitalization on Labor Market with Expanded Window (2009-2021)

| Variables | (1) Mean Salary | (2) Churn Rate | (3) New Hires Rate | (4) Separations Rate |
|---|---|---|---|---|
| Treated*COVID | 0.00*** | -0.49* | 0.57 | -0.75*** |
| | (0.00) | (0.26) | (0.43) | (0.28) |
| Constant | 1.72*** | 52.31*** | 35.96*** | 29.88*** |
| | (0.00) | (0.03) | (0.05) | (0.03) |
| Observations | 863,522 | 798,624 | 798,624 | 798,624 |
| R-squared | 0.81 | 0.33 | 0.37 | 0.33 |
| Firm FE | Yes | Yes | Yes | Yes |
| Sector#Year FE | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 10 with an expanded pre-treatment period covering 2009-2019. The main coefficient of interest, Treated*COVID is presented. Coefficients of other variables are not shown here for brevity. Each column presents a regression of column heading on the variables listed. Mean salary is deflated by CPI. Churn rate is defined as the sum of new hires and separations as a proportion of the total number of employees. New hires rate is the number of new hires as a proportion of total number of employees. Separations rate is the number of separations as a proportion of total number of employees. Firm fixed effects together with sector*year fixed effects are included in all regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

Table A.8: The Effect of Digitalization on Productivity with Expanded Window (2009-2021)

| | OLS | | Ordered Probit | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Variables | Sales / Emp. | Sales / Assets | Sales / Emp. (ranking) | Sales / Assets (ranking) |
| Treated*COVID | 0.01** | -0.01 | 0.00 | -0.00 |
| | (0.00) | (0.01) | (0.00) | (0.00) |
| Constant | 6.66*** | 1.61*** | | |
| | (0.00) | (0.00) | | |
| Observations | 1,023,716 | 1,032,605 | 1,026,676 | 1,035,198 |
| R-squared | 0.75 | 0.59 | | |
| Firm FE | Yes | Yes | Yes | Yes |
| Sector#Year FE | Yes | Yes | Yes | Yes |

*Notes: The table repeats the baseline regression presented in Table 11 with an expanded the pre-treatment period covering 2009-2019. The main coefficient of interest, Treated*COVID is presented. Each column presents a regression of column heading on the variables listed. Productivity is defined as sales per employee or total sales over assets. In the last two columns, we build categorical variables, placing firms into deciles based on their sales per employee and sales over assets at the 2-digit sector-year level respectively to run ordered probit regressions. Firm fixed effects together with sector*year fixed effects are included for the first and second regressions. Numbers in parentheses are standard errors clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.*

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