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INFORMATION TECHNOLOGY, FIRM SIZE, AND INDUSTRIAL CONCENTRATION

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ABSTRACT

Information flows, and thus information technology (IT) are central to the structure of firms and markets. Using data from the U.S. Census Bureau, we provide firm-level evidence that increases in IT intensity are associated with increases in firm size and concentration in both employment and sales. Results from instrumental variables and long-difference models suggest that the effect is likely causal. The effect of IT on size is more pronounced for sales than employment, which leads to a decline in the labor share, consistent with the "scale without mass" theory of digitization. Furthermore, we find that IT provides greater benefits to larger firms by increasing their capability to replicate their operations across establishments, markets, and industries. Our findings provide empirical evidence suggesting that the substantial rise in IT investment is one of the main driving forces for the increase in firm size, decline of labor share, the growth of superstar firms, and increased market concentration in recent years.

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1 Introduction

Advances in information technology (IT) and large declines in costs of storing, transferring, and analyzing digital information have reshaped our society and economy (Brynjolfsson and McAfee 2014). Since both firms and markets can be viewed as information processing systems (Hayek 1945, Galbraith 1974, Sah and Stiglitz 1986), the rapid diffusion of IT and sharp declines in its cost are likely to transform the organization of economic activities. This paper seeks to understand how investment in IT contributes to the firm's size as measured by employment, revenue, and market share, and consequently how IT plays a key role in the increasing industrial concentration in the last decades.

Earlier theories have linked IT with organizational structure (e.g., Brynjolfsson and Mendelson 1993, Brynjolfsson and Hitt 1998, Malone and Rockart 1991, Bloom et al. 2014) broadly and firm size in particular (e.g., Gurbaxani and Whang 1991, Brynjolfsson et al. 1994). On one hand, IT can substitute labor in production through automation and thus can lead to a smaller average firm size (e.g., Dewan and Min 1997). On the other hand, it can allow firms to expand production, and thus increase sales and aggregated employment (e.g., Tambe and Hitt 2012, Acemoglu et al. 2018).

Meanwhile, IT can also reduce the costs of information transfer and monitoring, and improve decision-making and overall efficiency through either moving information to decision-makers or moving decision rights to information (Brynjolfsson and Mendelson 1993). Because decision rights are associated with property rights (Garicano 2000, Grossman and Hart 1986, Hart and Moore 1990, Jensen and Meckling 1976), its effect on the boundary and structure of a firm thus depends on the relativity of transaction costs and coordination costs (Gurbaxani and Whang 1991). In both scenarios, the prediction of the average effect of IT on firm size is ambiguous and depends primarily on which effect dominates.

Several early studies found a negative correlation between IT and firm size, suggesting that labor substitution and reduction in market transaction costs were the dominant effects. For instance, Brynjolfsson et al. (1994) document a downward trend of average establishment size with respect to employment in the 1980s and provide evidence that IT investment was associated with the decline in the average size of both employment and sales using industry-level data from 1976 to 1989. Similarly, Hitt (1999) and Im et al. (2013) use firm-level data to investigate firm structure and both conclude that, the increased use of IT decreases the vertical integration firms and favors external markets.

However, more recent administrative data reveals a significant increase in average firm size in the U.S. (Figure 1), especially in Finance and Real Estate, Wholesale, Retail, and Services sectors (Figure 2). Along with these observations are the pronounced surge in market concentration[1] (Figure 3) for the corresponding sectors. Given the growing size of our economy, this implies a much faster increase in firm size for firms at top of the distribution (Hsieh and Rossi-Hansberg 2019, Autor et al. 2020). More importantly, (Autor et al. 2020) have also shown that increased industrial concentration and the rise of superstar firms is one of the potential driving forces of the declining labor share (Elsby et al. 2013, Karabarbounis and Neiman 2014). A similar pattern has been identified in the retail sector in particular where large national chains present a much higher net growth in recent years than smaller firms (Foster et al. 2016). Given the large implications of rising industrial concentration on the overall economy and our society (e.g., slower innovation, declining business dynamism, and increasing inequality), this phenomenon has been the focus of attention by both academics and policymakers in recent years.

Meanwhile, the aforementioned sectors also experience the most significant increases in IT investments as shown in Figure 4. Some anecdotal evidence further suggests that IT may be a major driver of the increased firm size and market concentration. For instance, IT played a central role in business innovation such as supply chain management that enabled Walmart to quickly duplicate its business operation and become a superstar firm which, based on a McKinsey Global Institute report, attributes one-sixth of the productivity growth in the retail sector, growing from 9 percent of the market share in 1987 to 30 percent around 2000 (Basker 2007, Freeman et al.

[1]In this paper, we use "industrial concentration" and "market concentration" interchangeably.

2011).[2] CVS is another example of how IT enables firms to replicate not only data and software but also business processes (McAfee and Brynjolfsson 2008). In 2002, CVS identified an issue within the prescription fulfillment process that caused high customer turnover but used IT to deploy and replicate a digital solution in its 4,000 nationwide pharmacies.

These uses of IT favor larger firms as its high-fixed-cost-low-variable-cost nature gives rise to increasing return to scale (Tambe and Hitt 2012, Feigenbaum and Gross 2021). In addition, larger firms typically have more organizational resources that complement IT and magnify the effect of IT to a greater scale (Brynjolfsson and Milgrom 2012, Brynjolfsson et al. 2021b).

Several recent studies have made the connection and theorize the relationship between the surges of IT and market concentration (Hsieh and Rossi-Hansberg 2019, Aghion et al. 2019). (Bessen 2020) further provides industry-level evidence linking the increasing industrial concentration with the diffusion of proprietary IT. However, large-scale firm-level empirical evidence is still lacking.

This paper examines the theoretical predictions by empirically investigating the relationship between firms' investment in IT and changes in firm size. We do so by using detailed micro-level data on a representative sample of U.S. firms based on the administrative data from the U.S. Census Bureau. Since our primary objective is to understand the overall impact of IT as a general-purpose technology, our preferred measure is the total IT capital investment. Furthermore, we seek to understand the mechanisms by which this relationship evolved and differed based on firm and sector heterogeneity, which ultimately contributed to increased market concentration in recent decades.

Our main findings suggest that investment in IT is associated with larger firm size with respect to both the level and shares of employment and sales in recent decades. Our results are robust to various specifications, fixed-effects, sample weights, and alternative IT measures. In

[2]See https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Americas/US%20productivity%20growth%201995%202000/usprod.pdf. Last access on June 20, 2021.

addition, following prior literature (Brynjolfsson and Mendelson 1993, Bessen 2020), we adopt long-difference models and the share of sedentary workers as an instrumental variable to tackle issues of measurement errors and endogeneity of firms' IT investment. Results from these estimations are broadly consistent and are especially strong when looking at sales as the dependent variable. This suggests that the positive relationship between IT and firms' size is likely causal.

Additional mechanism tests reveal that the effects of IT on firm size are more pronounced for larger firms, potentially through facilitating these firms to operate efficiently with a greater number of establishments, and helping firms enter more local markets and industries. These findings thus help explain the recent rise of industrial concentration and support the hypothesis that IT enables firms to replicate business processes with more production units, reach additional markets and industries, and thereby expand their sales without increasing their workforce proportionately.

The rest of this paper is organized as follows. Section 2 discusses relevant theories and their predictions, and walks through some related empirical studies and their finds; section 3 presents stylized facts in the US economy; section 4 describes the data used for this study; section 5 introduces the empirical methods; section 6 presents the empirical findings; and section 7 concludes.

2 Literature Review and Hypothesis Development

2.1 Costs of Information Transfer and Firm Size

In his classic paper, Hayek (1945) points out that information and knowledge are dispersed among all actors who participate in economic activities. Thus, decisions should be made by the person with information concerning particular circumstances of time and place for efficiency gain. Because a firm can be viewed as a nexus of contracts among self-interested individuals, within which conflicts of interest may occur (Jensen and Meckling 1976), the decision right should be accompanied by information and knowledge to maximize efficiency.

Moreover, these contracts are often ambiguous and incomplete, creating an important role for residual rights of control based on asset ownership. A well-designed incentive system will allocate decision rights in part via control of these assets (Grossman and Hart 1986). The costs of transferring and processing knowledge thus play a significant role in deciding the allocation of both property and decision rights and thereby the boundaries between firms and markets. Built on this line of thoughts, Brynjolfsson and Mendelson (1993) propose that, depending on the cost of information transmission and processing, matching decision rights can be achieved either by the information system solution (moving information to the decision-maker) or by the organization redesign solution (moving decision rights to information).

These have immediate and significant implications on firm sizes as widely dispersed information and knowledge should lead to decentralized decision-making and smaller firms, and vice versa (Garicano 2000). IT can reduce the costs of collecting, processing, and transferring information and knowledge. This not just enables the acquisition of dispersed knowledge and facilitates remote monitoring but also lowers the cost of information transfer to delegated decision-makers. In both scenarios, IT leads to better decision-making and improve efficiency for firms but can lower costs of coordination both internally and externally, leading to an ambiguous prediction of its impact on firm size from this lens.

Several papers note that the boundary and structure of the firm depend on the relativity of the effects of IT on transaction and coordination costs. Malone et al. (1987) argue that the overall effect of IT in reducing both the internal and external coordination costs should generally shift economic activities towards markets rather than hierarchies. Similarly, Clemons et al. (1993) argue that a lowered inter-firm coordination cost would encourage firms to outsource with a smaller set of stable partners without acquiring their ownership. Through the property right lens, Brynjolfsson (1994) argues that IT leads to reduced integration and, thus, smaller firms as: (1) it improves worker's information and therefore provides further incentives; (2) it leads to less lock-in in the use of physical assets; or (3) it enables decentralized coordination and reduces centralized coordination.

Early empirical studies did find that IT generally led to smaller firms on average. Brynjolfsson et al. (1994), who combine multiple data sources at the industry level, find that IT investment has been associated with subsequent decreases in the average size of firms using data from 1976 to 1989. Several other papers using micro-level data also found a negative relationship between IT investment and firm size during the 1980s and early 1990s. They attributed their findings to a reduced coordination cost between firms Im et al. (2001, 2013). Hitt (1999) further investigates the firm structure of 549 large public firms and concludes that the increased use of IT substantially decreases firms' vertical integration and favors external procurement.

On the other hand, IT can result in more integration and larger firms if its effect on internal coordination costs becomes more pronounced. This seems to be increasingly important in the last two decades, given the diffusion of information systems such as Enterprise Resource Planning (ERP), inventory, accounting, and HR management systems which allow low-cost firm-wide information sharing and transfer. Advances in cloud computing further enable ubiquitous intra-firm information access among all business units, reducing the cost of coordination. In conjunction with network externalities and economies of scale, IT will tend to support centralized ownership of assets, and hence larger firm size. The growth of "superstar" firms, documented by Autor et al. (2020), Covarrubias et al. (2020), Hsieh and Rossi-Hansberg (2019), as well as some empirical studies focusing on the retail sector(Basker et al. 2012, Doms et al. 2004, Foster et al. 2016, Hortaçsu and Syverson 2015), is consistent with the hypothesis that this mechanism has become more important in recent decades. Relatedly, Aghion et al. (2019) propose that accelerating IT advances lead to the falling firm-level costs of entering multiple markets, and, thereafter, become the driving force behind a series of economic phenomena including expanding firm boundaries, increasing markups, declining labor share, and rising industrial concentration.

2.2 Labor Substitution and Productivity Enhancement

In addition to its effect on transaction cost, investment in IT often directly enters a firm's production and therefore has a direct impact on its overall output and the use of labor. Technology in general, often-cited as a specific type of capital, can substitute labor in the production process (e.g., Arrow et al. 1961), and thus mechanically lead to smaller firm size with respect to firms' employment. If the substitution effect of IT dominates, firms that invest in such type of technology are expected to reduce their labor input. For instance, by evaluating the IT spending of large U.S. firms from 1988 to 1992, Dewan and Min (2008) find evidence that IT substitutes for labor input in production and subsequently leads to restructuring and downsizing. However, one overlooked dynamic factor in this line of argument is that firms that adopted advanced technology tend to have higher productivity, and thus increase overall revenue and aggregated employment (e.g., see Brynjolfsson and Mendelson 1993, Berndt and Morrison 1995, Acemoglu and Restrepo 2018 for examples).

Earlier studies point out a slowing down of productivity growth in the 1970s and 1980s despite the fast adoption of IT - "the IT productivity paradox" (Solow 1987). One of the main driven factors is the lack of accumulation of organizational innovation, complementary human capital, business process re-engineering, and other intangible assets (Brynjolfsson and Milgrom 2012). And the investment and accumulation of these intangible assets take time and therefore the productivity-enhancing effect of IT was not able to be captured by earlier empirical studies(Brynjolfsson et al. 2021a). Later studies find consistent results that IT has a positive and significant impact on firm profitability (e.g., Bharadwaj 2000) and productivity (e.g., Brynjolfsson and Hitt 2003, Tambe and Hitt 2012). Hence, the substitution of IT for labor does not necessarily result in smaller firm size, especially when given enough time for firms to accumulate complementary intangibles to fully realize the benefit of IT.

As firms accumulate intangible assets over time as IT further diffuses into our economy, increases in IT productivity could materialize and even become dominant in the long run. Combined with the nature of high fixed cost and economy of scale of IT, larger adopters tend to benefit significantly more and grow faster than their smaller counterparts, and potentially lead to an increasing concentration (e.g., Tambe and Hitt 2012). For instance, French manufacturing firms that adopted robots tend to have higher productivity with an expansion of overall employment and market share (Acemoglu et al. 2020).

Furthermore, by allowing firms with heterogeneous productivity to compete monopolistically, Hsieh and Rossi-Hansberg (2019) propose that IT is one of the key driving forces for the increasing firm size. They consider a simplified model where a firm pays fixed costs for operating in each industry and each location. While a new technology costs the firm higher fixed costs, it also increases the firm's productivity. However, high-productivity firms benefit more, compared with low-productivity firms, from adopting the new technology. One particular argument within their model is that IT, as the general purpose technology (e.g., Rosenberg and Trajtenberg 2004), enables the geographic expansion of firms (particularly in retail, services, and wholesale sectors) by lowering the costs of codifying and transferring information, as well as monitoring. This is consistent with Zolas et al. (2020) who report that advanced technology adoption is heavily skewed towards larger and more productive firms. And consequently, IT appears to primarily enhance the productivity of larger firms, with a lag that can be attributed to the need for both tangible and intangible complementary assets accumulation (Bresnahan et al. 2002, Tambe et al. 2020).

As the result, firms with higher productivity will further increase their size in overall employment and revenue. These firms also tend to enter more markets and to be more profitable relative to average or low-productivity firms. Therefore, a menu of new technologies increases industry concentration in the long run. Several recent studies have documented an increase in market concentration across a wide range of sectors - especially in wholesale, retail, and service sectors in the U.S. economy, in which IT is mostly identified as a potential cause (e.g., Autor et al. 2020, Hsieh and Rossi-Hansberg 2019). Furthermore, Kwon et al. (2022) provides evidence that the rising concentration was primarily present in the manufacturing and mining sectors before 1970 but was then stronger in services, retail, and wholesale sectors afterward, in parallel with the timing of IT adoption across sectors. In a recent paper, Bessen (2020) further analyzes industry-level concentration data from the U.S. Census and finds a strong link between IT and the rising industry concentration.

2.3 Hypothesis Development

Although the aforementioned theories have an ambiguous prediction on the firm size in general, the recent development of IT and its effects on firms, especially when accounting for the decline of internal coordination cost and the accumulation of investment in complementary intangibles in recent years, favors increasing return to scale, and hence more likely to lead to larger firm size. We, therefore, hypothesize that:

Hypothesis 1 (Employment and Revenue) *Investment in IT allows the firm to expand its size in employment and to operate on a greater scale with large sales.*

However, the effect of IT on revenue likely significantly differs from its effect on employment given that IT increases labor productivity (Dunne et al. 2004). Both Aghion et al. (2022) and Acemoglu et al. (2020) report similar findings where automation and robots lead to a significant decline in labor share. In addition, today's digitized firms are able to utilize the network effect in a more cost-efficient way that is enabled by the process of IT and reach a much greater scale of markets with a relatively much smaller employment size (Parker and Van Alstyne 2005). Consistent with prior studies, we argue that IT allows firms to scale up their business without the same degree of expansion on the labor and hence leads to the phenomenon of scale without mass (Brynjolfsson et al. 2008).

The different effects of IT also imply a declining labor share. Indeed, a series of papers presents the trend of declining labor share to income in the United States (Elsby et al. 2013) and worldwide (Karabarbounis and Neiman 2014). And the relationship between the declining labor share and automation is well documented in both aggregated level (Autor and Salomons 2018, Acemoglu and Restrepo 2020) and micro level (Acemoglu et al. 2020 for France) analysis. Autor et al. (2020) attribute the declining labor share to the rise of superstar firms which is associated with increased productivity due to technology adoption. As a natural extension of the discussion in the paragraph above, we also test the effect of IT on firms' labor share. Therefore, our next hypothesis focuses on the heterogeneous effects of IT on firms' sales versus their employment, and thereafter the impact of IT on labor share is as follows:

Hypothesis 2 (Effect on revenue is greater than the effect on employment) *IT increases the firm's revenue to a greater scale than its effect on firms' employment, and therefore leads to a decline in labor share.*

IT makes replication of business processes much cheaper in today's digital economy (Brynjolfsson et al. 2008) and allows for larger and more productive firms to implement their business model to a large number of markets in a relatively cheaper way. It allows firms to establish more plants and reach more local markets through which firms become larger and more dominant (Hsieh and Rossi-Hansberg 2019, Aghion et al. 2019). We therefore propose and test the following hypothesis:

Hypothesis 3 (Markets) *Firms with higher investment in IT set up more establishments and enter more local markets.*

Finally, as the realization of the full potential of the investment in IT shall be complemented with other assets, typically intangible assets, which are more likely to be found in larger and more productive firms, the effect of IT should be more pronounced on larger firms than those small non-productive firms (Brynjolfsson et al. 2021a). Tambe et al. (2020) point out that a small set of "superstar" firms account for a great proportion of digital capital. Therefore, as large firms accumulate a greater level of digital assets and arrive at the technology frontier, their advantage leads them to expand their sizes to a greater scale.[3] This heterogeneous effect of IT favoring larger firms tends to create a winner-take-most effect that increases market concentration. To evaluate this idea, we will also test the following hypothesis that studies the effect heterogeneity of IT:

Hypothesis 4 (Concentration) *The effect of IT investment is more pronounced among larger firms than smaller firms and, therefore, increases the industrial concentration rates.*

[3] Although Tambe and Hitt (2012) report that the productivity-enhancing effect of IT is greater for larger firms, less is known regarding its effects on transaction and coordination costs conditional on firm size, and thereafter whether IT contributes to the increased market share of large firms and industrial concentration.

In contrast to prior studies which either provided industry-level evidence or focuses on a single sector, our study provides a US-economy-wide representative study carried out at the firm level exploring the effect of IT on firm size. This paper attempts to identify the micro-level mechanisms that drive the documented wide-spread phenomena and provide a causal link between the increasing firm size and industrial concentration with IT.[4] We do so by taking advantage of a large number of micro-level census data that allow us to construct a representative sample of the U.S. economy. Below we first present relevant overall stylized facts based on our data at both industry and firm-level.

3 Stylized Facts in the US Economy

Based on the Business Dynamics Statistics (BDS) data from the US Census, the average firm size by employment has been increasing since 1978, as shown in Figure 1. Breaking down the aggregated data into six major sectors, Figure 2 shows that the growth of firm employment has occurred primarily in three sectors: wholesale trade, retail, and service.[5]

To further explore this trend, we evaluate the industrial concentration rate in the private sector from 1976 to 2016 using confidential data from the US Census Bureau.[6] We calculate the employment and sales concentration rates from Revenue-enhanced LBD (LBDRev) at the six-digit NAICS level respectively, then compute the weighted averages of industries within the six major sectors.[7] Figure 3 presents the Concentration Rate 4 (CR4), the share of the largest

[4]To the best of our knowledge, the paper most closely related to ours is Lashkari et al. (2019), who investigate this topic using French data. They find that IT intensity strongly correlates with firm size and explains the changes in concentration in the France context.

[5]These sectors are 1. Manufacturing, 2.Finance and Real Estate, 3. Utilities and Transportation, 4. Wholesale Trade, 5.Retail Trade, and 6. Services. Please see detailed section definitions in Autor et al. (2020), Hsieh and Rossi-Hansberg (2019).

[6]Please see detailed discussion of this data below in section 4.

[7]The weights are calculated using the average employment share of each industry.

four firms in the industry, for both employment and sales. Consistent with the findings of earlier studies, over the last four decades, the employment concentration increased in most sectors (except manufacturing).[8] However, the increase in concentration is more pronounced when it is measured by sales. Such a phenomenon is consistent with the "scale without mass" digitization hypothesis (Brynjolfsson et al. 2008). This is true for most sectors including Finance and Real Estate, Wholesale, Services, and even Manufacturing. Additionally, consistent with Autor et al. (2020), these trends for market concentrations are robust when other concentration ratio measures are used (i.e., CR20 and Herfindahl-Hirschman Index (HHI)).[9] We also explore the evolution of the share of top 10% firms, another measure of industrial concentration, as a robustness exercise. The results, shown in Appendix Figure A2, resemble a similar trend displayed in Figure 3. Further validation test indicates that the average change of the log employment share during this period based on our data is similar to those reported in Hsieh and Rossi-Hansberg (2019).[10]

One particularly interesting pattern is that the sectors with high growth in firm size and industry concentration (i.e., Wholesale, Retail, Services, and Finance and Real Estate) also had the most rapid growth of IT capital investment. As shown in Figure 4, the real total IT investment grew rapidly after 2000 and was more pronounced in the sectors that experienced higher growth in market concentration, implying a positive correlation between the two.[11] In section 6.6, we further

[8]Consistently, the evolution of firm size distribution is also evident in the skewness of firm size distribution, especially towards the right tail, as shown in Appendix Figure A1.

[9]CR20 indicates the concentration ratio of the top twenty firms. HHI is the summation of the squared market share of each firm in the industry. Please see https://www.justice.gov/atr/herfindahl-hirschman-index for more details.

[10]Hsieh and Rossi-Hansberg (2019) calculate the share of the top 10% for consistent four-digit SIC codes. Our paper makes use of time-consistent six-digit NAICS codes provided by Fort and Klimek (2016).

[11]We calculate the total IT capital investment by summing the capital investments for all IT equipment and software categories including mainframes, PCs, DASDs, printers, terminals, tape drives, storage devices, system integrators, prepackaged software, custom software, and own-account software using the private asset investment series between 1977 and 2018 from the Bureau of Economic Analysis. Our figure is based on the data updated on September 2, 2020.

examine how the surge of IT in recent years is associated with increases in firm size and industrial concentration using restricted-use firm-level data from the Census Bureau.

In the figures described above, we present the aggregate trend in the U.S. economy with the following stylized facts: (1) average firm size has been growing with respect to both employment and sales, particularly in wholesale trade, retail, and service sectors; (2) market concentration has also increased in those sectors, and is more pronounced in sales than employment; and (3) sectors with faster increases in average sizes and concentration rates are also the ones with faster growth in IT expenditures. This paper seeks to explain the macro-level trends by investigating the role of IT in the micro-level mechanism.

4 Data and Summary Statistics

Most of the firm-level IT investment data in prior studies have limited sample coverage and predate the early 2000s (see Tambe and Hitt (2012) for a review). To overcome this issue, we examine a unique firm-level data set from the U.S. Census: the Annual Capital Expenditures Survey (ACES) and its supplement, the Information and Communication Technology Survey (ICTS) from 2004-2013 (excluding 2012 due to the suspension of ICTS).[12] The U.S. Census Bureau collects data on non-capitalized and capitalized business spending for Information and Communication Technology Equipment and Computer Software in the ICTS. It covers all domestic, private, and non-farm businesses, including non-employer businesses. According to the Census website, all large firms with at least 500 paid employees are selected from the Business Register (BR) into the sample frame while smaller companies are stratified by industry and payroll size and selected randomly by strata, resulting in a stratified random sample of roughly 45,000 companies with paid

The data can be accessed from https://apps.bea.gov/national/FA2004/Details/Index.htm.

[12]Although the ICTS started in 2003, IT expenditure variables were not recorded during the first year. Thus, we examine these data starting in 2004. Additionally, because of the government shutdown, ICTS was not conducted in 2012.

employees, as determined by having nonzero payroll in the previous year.

The key IT-related variables for our study in the ACES and ICTS are IT-related equipment expenditures and capitalized software purchases. In contrast to the external IT data, these databases contain rich and high-quality firm-level IT capital expenditure information for a larger representative sample and can be merged with other surveys conducted under Title 13 (e.g., the LBDRev) to gain access to related firm matrices. One limitation worth noting here though is that the ICTS was suspended in 2013 due to reductions in Census Bureau funding levels.[13] Also available in the ACES database is total capital expenditure, which allows us to measure and control in our analysis for non-IT related capital expenditure.

Complementary to the firm-level IT measures from the ACES and ICTS data, we employ the Revenue-enhanced version LBD (LBDRev) to access restricted information on firm employment, sales, and relevant aspects of firm structures, including the number of establishments, number of counties in which a particular firm has operations, firm age, and firms' core industry definition. The LBDRev is a product of the U.S. Census's effort of redesigning the earlier longitudinal business database (i.e., LBD) that incorporates information from the Statistics of all private U.S. businesses Chow et al. (2021). It also includes the firm-level employment and revenue information that is documented in the Business Register (Standard Statistical Establishment List Files prior to 2002) data.[14] Given the objective and its prominence, the coverage and quality ensured by the U.S. Census Bureau is hard to match using external resources.

With access to these data, we can report not only the stylized facts above but also build a large sample of U.S. firms (private and public) with their IT capital expenditures, employment,

[13] Also note that the firm-level data from the ACES and ICTS is the source for the BEA industry-level data of private nonresidential fixed assets, which we use later to explore IT investment trends across major sectors.

[14] For more details of LBD, please see the Census website at: https://www.census.gov/programs-surveys/ces/data/restricted-use-data/longitudinal-business-database.html. For more information on LBDRev, please see Decker et al. (2016). The original version of LBD was initially introduced by Jarmin and Miranda (2002) to create official tabulations to describe the dynamics of the U.S. economy.

sales, and other metrics that allow us to further explore the relationship between IT investment and these dynamics. To ensure data quality, and for the purpose of empirical analysis, we drop firms with missing values in IT capital expenditure variables (in the ACES/ICTS) and firms that have zero employees and/or sales (in the LBD and LBDRev). In so doing, we build panel data for about 5000 firms from 2004 to 2013 (excluding 2012, which lacks ICTS survey data).[15]

For this firm-level data, both mean and standard deviation are reported for all key variables in Table 1. The sample means for the total number of employees exceeded 3,800 and the average annual sales were over one billion U.S. dollars. The average total annual capital expenditure was slightly over 65 million dollars, about 20% of which was allocated to IT. And on average, firms in our sample spend about six thousand dollars per worker on IT every year. These firms on average have about 2.4 and 3.4 percent of the shares in employment and sales, respectively, in their core industry. In addition, these firms on average have 77 establishments, operate in geographic locations with nearly 60 different zip codes, and do business in 4 different six-digit industries. Given these descriptive, it is likely that our sample biases toward larger firms, similar to those in the earlier IT productivity literature (e.g., Tambe and Hitt 2012). However, both ACES and ICTS are purposely designed to capture primarily IT capital investment activity in the U.S. and to be representative, thus relieving concerns about selection bias.[16] Moreover, we conduct additional analysis using weighted regression using the ACES and ICTS sample weights to further test the robustness of our findings against the sample selection issue.

[15]According to the census policy, we round the actual number to the level of thousands.

[16]For more information regarding the sample selection method of the ACES and ICTS, please see the Census websites at: https://www.census.gov/econ/overview/mu2200.html and https://www.census.gov/econ/overview/mu2500.html.

5 Empirical Methods

To test our Hypothesis 1, we start by exploring the relationship between firms' investment in IT and their size, measured either by employment or sales. More importantly, we are able to, for the first time, directly measure firms' employment and sales as shares of the total employment and sales of its core industry, and, thereafter, directly link these to industrial concentration because our data covers the universe of the U.S. employers in the private sector. In order to tease out the size effect on IT expenditure, we employ IT intensity as our key IT measure by defining it as the IT capital expenditure per worker, following Tambe et al. (2020).[17] The equation can be described as follow:

$$Size_{i,j,t} = \beta_0 + \beta_1 IT_{i,j,t} + \beta_2 nonIT_{i,j,t} + \beta_3 IT_{i,j,t-1} + \beta_4 non_I T_{i,j,t-1} + \beta_X X_{i,j,t} + \varepsilon_{i,j,t} \quad (1)$$

where for each firm i, in the six-digit NAICS industry j, $IT_{i,j,t}$ indicates the measure of IT intensity in year t while $IT_{i,j,t-1}$ indicates the measure of IT intensity in the previous year $t-1$. We also include the measure of non-IT capital expenditure intensity, $nonIT_{i,j,t}$, and its one-year lag, $nonIT_{i,j,t-1}$, to control for the effect of capital expenditure.[18] Here, the main coefficients of interest are β_1, which captures the effect of IT expenditure on firm size for a firm i in industry j in year t. In addition, $X_{i,j,t}$ is a vector of controls that include firm fixed effects, year fixed effects, and industry fixed effects. The firm fixed effects capture time-invariant firm heterogeneity; the year fixed-effects capture the economy-wise homogeneous yearly changes; the industry fixed-effects capture the time-invariant industry-specific unobservables. Both the IT and non-IT measures are in logarithmic forms, as are the size measures. $\varepsilon_{i,j,t}$ is the error term. Standard errors are clustered at the firm level.

Additionally, to test Hypothesis 4 and examine whether IT affects the firms with different

[17]We also use the firm's total IT expenditure level as the regressor for robustness check and report the results in the Appendix.

[18]Similar to the construction of IT intensity variable $IT_{i,j,t}$, we construct the non-IT intensity as the total non-IT expenditure per worker.

sizes to a different extent, we explore the heterogeneous effect of IT across firms of different sizes by including the firm size quintiles in the model, as shown below:

$$Size_{i,j,t} = \beta_0 + \beta_1 IT_{i,j,t} + \beta_q Q + \beta_{it,q} IT_{i,j,t} \times Q + \beta_2 nonIT_{i,j,t} + \beta_3 IT_{i,j,t-1} + \beta_4 onoIT_{i,j,t-1} + \beta_X X_{i,j,t} + \varepsilon_{i,j,t} \tag{2}$$

Here, Q is a vector of the indicators for different firm size quintiles. We also include the interaction term of the size quintile indicators and IT investment variable. So the coefficients $\beta_{it,q}$ for each quintile describe the effect difference of IT on that particular size group from the base size group. And the combination of $\beta_{it,q}$ and β_1 together captures the heterogeneous effect of IT across size groups.

5.1 Identification Strategy

Although our fixed effects models control for the firm, industry, and year fixed effects, estimates from earlier specifications might still suffer from the endogeneity issue. For instance, large firms with more resources could be more likely to invest in IT (Dewan et al. 1998) and thus lead to an upward bias on the estimate of IT. Although Tambe and Hitt (2012) find such concerns are less severe in this context, we apply the following strategies to address this potential issue. First, we leverage long-difference models as it is less likely to be subject to biased estimates from measurement error (Greene 1993). This method is adopted in various economic studies in general (e.g., Acemoglu and Restrepo 2018, 2020) and IT productivity research in particular (e.g., Brynjolfsson and Mendelson 1993, Tambe and Hitt 2012).

We further adopt the share of sedentary employees at the industrial level as the instrumental variable (IV) to estimate the effect of IT intensity on a firm's employment and sales, following Bessen (2020). Given that sedentary workers are more likely to work with computers and other IT technologies, firms in industries that have a higher proportion of sedentary workers would, therefore, tend to adopt new IT technology earlier and more intensively. Building upon the Dictionary of Occupational Titles (DOT) (US Department of Labor 1977), England and Kilbourne (2013) map the sedentariness of nearly 14,000 jobs to census occupation codes.[19] Bessen (2020) calculates the distribution of sedentary occupations for industries using the 2000 census public-Use micro-data, four years before our data begins. In conjunction with the fact that a firm's sedentary workforce is likely being influenced by its peers in the same industry, the lagged industrial-level sedentariness is arguably exogenous to a firm's size in the future years. The final data of our IV include 264 industries that are mostly at four and five digits of NAICS codes. On average, the proportion of sedentary workers is about 43.5%.

6 Results

6.1 IT Intensity and Firm Size

The baseline results following specification (1) are presented in Table 2. Panel A presents the results from the pooled OLS regressions examining the correlation between IT intensity and the firm's future employment and market share of employment. Given the definition of IT intensity (i.e., using total employment as the denominator), it is negatively associated with a firm's employment by construction. Therefore, we use employment and employment share at $t + 1$ as our outcome variable. Columns 1 and 2 present the results for employment while columns 3 and 4 present the results for employment share in its core industry. In column 1, The coefficient on $log(ITintensity)$ shows that a one percent increase in IT intensity is associated with a 0.056 percent increase in firm employment in the following year. The result is similar when we control for IT and non-IT intensities in the previous year, as presented in column 2. Similarly, column 3 shows that the following year, a one percent increase in IT intensity is associated with a 0.015 percent change in the firm's share of total industrial employment size. Controlling for IT and non-IT intensities in the previous year does not change our estimate qualitatively as shown in column 3. All columns in

[19] This data and its description can be accessed via this link: https://www.icpsr.umich.edu/web/ICPSR/studies/8942.

Panel A of Table 2 control for year, industry, and firm fixed effects.

We conduct a similar exercise using sales and market share of sales and present the results in Panel B of Table 2.[20] Controlling for employment, columns 1 and 2 in Panel B show that a one percent increase in the firm's IT intensity measure is associated with approximately 0.1 percent increase in sales. Columns 3 and 4 show the regression results when a firm's sales share is the dependent variable. They show that higher IT intensity is also associated with higher sales and large market shares.

In addition, we perform additional robustness tests. Table 3 presents results from alternative specifications. For each left-hand side variable in Table 2, we include additional variables that control for the number of establishments, the number of zip codes the firm operates in, and the number of industries in Columns 1 and 3 in Panels A and B, respectively. Results are largely similar to those in the corresponding columns in Table 2. Columns 2 and 4 in both panels report results from weighted regressions using the ACES sample weights to address potential selection bias.[21] These results are also consistent with the baseline results in Table 2. We also use IT expenditure as an alternative IT measure and present the results in Table A2. Panel A presents the results for firm employment while Panel B presents the results for firm sales. In both panels, the results are similar to those reported in our baseline models. The coefficients of IT are consistently large, positive, and highly significant, suggesting that higher IT capital investment is positively associated with an increase in firm size with respect to employment, sales, and the corresponding market shares in their core industries.

[20]We use contemporaneous sales and market share of sales in this set of analysis as the calculation of IT intensity measure has not involved them directly.

[21]The sample of ACES is selected based on the Business Register (BR). As stated by Census, all companies with at least 500 paid employees are included in the survey; and smaller companies with employees are stratified by industry and payroll size and selected randomly by strata. Companies without employees are selected randomly without regard to industry classification. Please see more details at https://www.census.gov/programs-surveys/aces/about.html.

One interesting observation from the results above is that the estimated coefficients of IT are generally larger in specifications that use sales as the outcome variable than those that use employment (e.g., Comparing the coefficients in columns 1 and 2 in Panel B and Panel A across the tables above). As both the outcome and explanatory variables are in log terms, this suggests that the elasticity of IT investment on sales is more pronounced than its elasticity on employment. This is likely because IT allows firms to improve labor productivity, and thus increase sales without proportionately increasing their labor - a result consistent with the findings of Brynjolfsson et al. (2008), Tambe and Hitt (2012), Acemoglu and Restrepo (2020), and in line with "scale with mass" theory and the declining trend of labor share, which we explore further in the latter sections.

6.2 Identification: Long-Difference Models and Instrumental Variable Estimates

Although Tables 2 and 3 provide suggestive results that an increase in IT intensity is associated with larger firm sizes and higher market shares, these results might still suffer from the potential endogeneity issue. For instance, as noted by Dewan et al. (1998), the scale, scope, and, more importantly, the boundaries of the firm can also affect demand for IT. This implies that the adoption and investment of IT is likely an endogenous choice and thus could cause an upward bias (see (Tambe and Hitt 2012) for a detailed discussion). Therefore, we follow prior literature and employ both long-difference and IV approach models in sections 6.2.1 and 6.2.2, respectively.

6.2.1 Long-Difference Models

We first apply long-difference models, which help further tease out measurement errors and strengthen identification (Brynjolfsson and Hitt 2003, Acemoglu and Restrepo 2020). The results are provided in Table 4. Columns 1 to 5 of Panel A present the results for employment from one-year-difference to five-year-difference specifications, respectively.[22] Similar to previous sections, the left-hand side variable is also the firm's log employment in year $t + 1$. In all specifications, we control for firm, year, and industry fixed effects. Although column 1 shows that the change in IT intensity is positively correlated with the change in employment, according to the on-year-difference model, the magnitude of the coefficient is only less than half of the coefficients shown in Table 2 Panel A. And the magnitude of the coefficient for the two-year-difference model is even smaller while it is only statistically significant at the 5 percent level. Furthermore, when it comes to a longer period, the effect of IT intensity on employment is no longer present, as shown in three-year to five-year differences models. These results suggest that the increased IT intensity tends to have a short-term effect on firms' employment size and to a smaller extent than Table 2 suggests.

On the other hand, Panel B of Table 4 reports the results of difference models using sales as our outcome variable. The results are largely consistent with our findings above, with respect to sales. Coefficients from one-year to five-year differences models are all positive and significant at the one percent level, suggesting that an increase in firm IT intensity is associated with larger firm sales, especially during the first three years. However, the effect of IT intensity on sales seems to fade away over the long run as the coefficients decrease and are less statistically significant. Nevertheless, by comparing the results for employment in Panel A where the effect of IT intensity seems to be short-lived, the effect on firms' sales seems to be more pronounced and more persistent.

These results provide some supporting evidence for the causal relationship between the increasing IT intensity and firm size as measured by employment and sales, consistent with those presented in Tables 2 and 3.

[22]Given the length of our panel data and to ensure we have large enough samples for statistical inference, we report results from difference model up to five-year difference.

6.2.2 Instrumental Variable Estimates

As noted by Dewan et al. (1998), the scale, scope, and, more importantly, the boundaries of the firm can also affect demand for IT. This indicates that the adoption and investment of IT are likely an endogenous choice and thus could cause an upward bias (see (Tambe and Hitt 2012) for a detailed discussion). To further investigate this causal relationship between IT and firm size, we use the share of sedentary workers at the industry level to instrument for IT intensity and present results in Table 5. In all specifications, the first stage shows that our IV is highly correlated with firm IT intensity.

Columns 1 and 2 in Table 5 present the results for employment in year $t+1$. All specifications control for the firm's non-IT intensity, current year employment size, and year fixed effect and the coefficient of interest is the IT intensity. Column 2 controls for additional industry fixed-effects at three-digit level of NAICS, which is the best we can do as our instrumental variable is largely at four-digit level. Unlike the results presented in earlier Tables 2, 3, and 4, columns 1 and 2 here show no statistically significant coefficients on IT intensity. This reveals a surprising non-effect of IT intensity on firm size with respect to employment in the IV estimation and weakens the causal argument for Hypothesis 1 that IT increases firms' employment.

Columns 3 and 4 in Table 5 examine the impact of IT on sales following the same IV strategy. In contrast to the results for employment, both columns 3 and 4 show that a higher IT intensity leads to a larger firm size in sales, largely consistent with the findings in earlier models. A one percentage increase in IT intensity is associated with about a 0.65 percent increase in firms' sales. The comparison between these results and the ones for employment (columns 1 and 2) suggests that investment in IT likely enhances a firm's sales performance without expanding its employment, consistent with the phenomenon of scale without mass (Brynjolfsson et al. 2008).

6.3 IT intensity and Labor Share

Previous sections provide evidence that IT intensity could lead to faster growth in firms' sales but without expanding its employment to a similar scale, suggesting a declining labor share of firms' output. In this section, we take a further step and analyze the relationship between the investment in IT and the firm's labor share. Similar to the previous sections, we study such correlation by estimating Equation 1 with firm-level labor share as the outcome variable of interest. We follow Autor et al. (2020) and define labor share as the ratio of payroll to sales. Table 6 presents the results. The baseline result in Panel A column 1 shows that a one percent increase in IT intensity is associated with a 0.1 percent decline in labor share. And the results are robust across specifications with lagged independent variables (column 2), with additional controls for the number of establishments, zip codes, and industry (column 3), and weighted regression (column 4). In addition, following Sections 6.2.1 and 6.2.2 to address the potential endogeneity issue, we also adopt long-difference models and IV strategy and present the results in Panel B of and Columns 5 to 6 of Panel A in Table 6, respectively. The results are largely consistent with the baseline result, indicating that the negative correlation between IT intensity and firms' labor share is likely causal.

6.4 Mechanism Tests

As discussed earlier in Section 2, IT allows firms to codify their operation, facilitate duplication of their business process in more production units and markets, and thus lead to larger firm size. We further investigate this mechanism and test whether IT is associated with additional outcome variables of interest including the total number of establishments, number of zip codes, and industries that firms operate in, and present the results in Table 7.

Panel A presents the correlation between IT and the number of establishments and shows that a one percent increase in IT intensity is associated with a 0.03 percent increase in the number of establishments. Similarly, Panel B and Panel C show that IT is also associated with the increase in the number of zip codes and the number of industries, respectively. The coefficients for IT within

IV strategies using the sedentariness of employees are also positive and statistically significant, as presented in Columns 3 and 4 of each panel. These results suggest that investment in IT is likely to increase the firm size through its capability of lowering internal coordination and business process duplication costs, allowing firms to expand with more establishments, and enter additional physical and product markets.

6.5 Effect Heterogeneity and Implication in Industrial Concentration

Given that the benefits of economies of scale and the accumulation of tangible and intangible complements benefit larger firms (e.g., Acemoglu and Restrepo 2018, Feigenbaum and Gross 2021, Tambe and Hitt 2012, Bresnahan et al. 2002, Brynjolfsson and Milgrom 2012, Brynjolfsson et al. 2021b, the contribution of IT to firm growth is likely to vary across firm size groups as they are more likely to grow through the aforementioned enabling effects of IT.

Following equation 2, we thus estimate the marginal effect of IT intensity on firm size across firms of different sizes and plot the regression coefficients for employment, sales, and labor share in Figure 5. Here, we split firms into quintiles according to their position in the distribution of sales within their primary industry.[23] The result in Panel (a) indicates that a higher IT intensity is associated with greater employment for all size quintiles although the effect of IT seems to have a greater effect on small firms while larger firms are affected to the extent by a relatively smaller scale in terms of the percentage change. However, because the average firm size increases fast from the first to the fifty quintiles, the effect magnitude in terms of level actually increases monotonically.

Similarly, the result in Panel (b) shows that a higher IT intensity is also associated with greater sales but this effect increases monotonically with firm sizes and is only significantly different from zero for larger firms. This suggests that although the average effect of IT on firms' sales might be positive, the disproportional larger gain for larger firms suggests an increasing return to scale of IT investment. Given the extensive business adoption of IT across a wide range of industries,

[23]This is also to ensure that we comply with the US Census disclosure avoidance rules.

our results here provide supporting evidence that IT is one of the driving forces for increasing concentration over time, which we explore further using industry-level analysis in Section 6.6. In addition, the larger effects of IT on sales (compared to employment) are more pronounced among the firms in larger size quintiles.

As we have already shown in earlier tables, the estimated effect of IT on sales is much larger than its effect on employment, especially in the IV estimation (see columns 1 and 2 in both panels of Table 5) and thus would on average lead to a decline in labor share (i.e., Table 6). In panel (c), we further reveal that this effect is much more pronounced in larger firms. In fact, the effect of IT on labor share is positive (though noisy) for firms in the bottom size quintile but declines across the size categories, and becomes more negative and highly significant for firms in the top three size quintiles. This is consistent with the results presented in Panels (a) and (b).

6.6 A Revisit - IT Expenditure and Industrial Concentration

In the above section, we demonstrate that IT provides disproportional benefits to larger firms, implying that the adoption of IT is one of the factors of the increasing industry concentration. Therefore, following Bessen (2020) we aggregate our data and conduct an industry-level analysis using long-difference model (Brynjolfsson and Hitt 2003, Bessen 2020).[24] The basic equation can be described as equation 3, as shown below:

$$\Delta Concentration_j = \beta_0 + \beta_{IT} \Delta IT_j + \varepsilon_{j,t} \quad (3)$$

Where for each industry j (at the six-digit NAICS level) in year t, $\Delta Concentration_j$ indicates the difference in the industry concentration (e.g., HHI, CR4, and Top 10% for both employment and sales) between 2004 and 2013. ΔIT_j indicates the differences in average IT hardware and software capital expenditure between 2004 and 2013 in a given industry. The coefficient of interest in equation 3 is β_{IT}, which indicates how a change in IT expenditure contributes to a change in industry concentration.

[24] We employ the longitudinally consistent 6-digit FK NAICS codes.

The corresponding results from the regression above are presented in Table 8. Columns 1 to 3 present results of three widely used industrial concentration measures–HHI, CR4, and the share of employment in the top 10% firms–while columns 4 to 6 present results from similar models for sales. The left-hand side variables are the change in log industrial concentration measures between 2004 and 2013. The right-hand side variable in all specifications is the difference in log IT expenditure between 2004 and 2013. The regression samples consist of 815 six-digit NAICS industries.

As indicated in columns 1 to 3 in Table 8, the change in IT capital expenditure is positively and significantly associated with changes in employment concentration as measured in all three different metrics. This indicates that industries with a larger IT expenditure growth during the period of 2004 to 2013 also experienced a faster increase in industrial concentration. In column 1, for example, an one percent increase in the industry average IT expenditure was associated with about a 0.08 percent increase in the employment HHI index. Columns 2 and 3 show similar relationships for different measures. Likewise, columns 4 to 6 in Table 8 indicate that the change in IT capital expenditure is positively correlated with the sales concentration measures. The coefficient of $\delta log(IT)$ presented in column 4 is 0.08, a magnitude similar to the coefficient in column 1. All results are statistically significant at the one percent level. Our findings are largely consistent with those in the prior study (Bessen 2020).

Combining these findings with earlier results in Figure 5, we document an effect of IT that leads to increased market concentration with the rise of superstar firms in the last decade. It further indicates a troubling trend where a significant amount of the workforce will be substituted by IT as firms become more digitized with larger and more productive firms dominating our economy.

7 Summary and Conclusion

Economic activities, either within firms or in markets, are accompanied by information processing. Over the past several decades, as digital technology has advanced, the cost of information processing has declined significantly. As a result, it would be surprising if IT did *not* affect the boundaries of firms and markets.

Recent evidence shows that the average firm size and industrial concentration in the U.S. have increased, particularly in those sectors with the sharpest increases in the adoption of IT such as wholesale, retail, finance and real estate, and services sectors. This suggests that lowering internal coordinating cost and/or enhancing productivity with market expansion have been the dominant effects of IT in recent years.

In this paper, we start with documenting a set of stylized facts. First, we show both the average firm size and industrial concentration rates are increasing for a number of major sectors in the last two decades. The rising industrial concentration appears in both employment and sales but has been most pronounced in sales. Meanwhile, the sectors with higher growth of the average firm size and industrial concentration also show a more rapid increase in IT investment.

Our study further provides empirical evidence that the adoption of IT is associated with the increasing firm size in the last decades. Taking advantage of US Census firm-level data, we provide evidence that a higher IT intensity is associated with larger firm size, growth in sales, as well as increases in the corresponding market shares of the largest firms. Our findings are robust to alternative specifications such as adding lagged IT measures, additional controls, and weighted regressions. Our results are also robust when using alternative IT measures.

long-difference models spanning up to five years provide additional evidence that the relationship between IT and firm size is likely to be causal. Results using the share of sedentary workers at the industry level as an instrument for IT adoption provide further evidence suggesting that the identified positive effect of IT on firm size, especially sales, is causal.

Furthermore, the effect of IT on sales is significantly larger than its effect on firm employment, consistent with the "scale without mass" prediction. In addition, we investigate the underlining mechanisms through which the higher IT intensity leads to larger firm size. Taking advantage of the detailed firm-level data, we first provide evidence that investment in IT enables business replication and allow firms to enter more local markets and industries. These results are also robust with the IV strategy.

We further show that the relationship between IT and firm size is particularly pronounced in larger firms. The enabling effect of IT and the heterogeneity effect of IT across firm size groups thus speak to the debate that IT has an important impact on market structure and contributes to the rise of industrial concentration and the growth of superstar firms. Our findings remain robust when various measures of firm size and industrial concentration (both level and shares of employment and sales) are employed, and when various IT measures are used. long-difference models at the industry level also confirm that industries with a larger IT investment experienced a faster increase in industrial concentration, a result that is consistent with the prior study (Bessen 2020).

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Figures and Tables

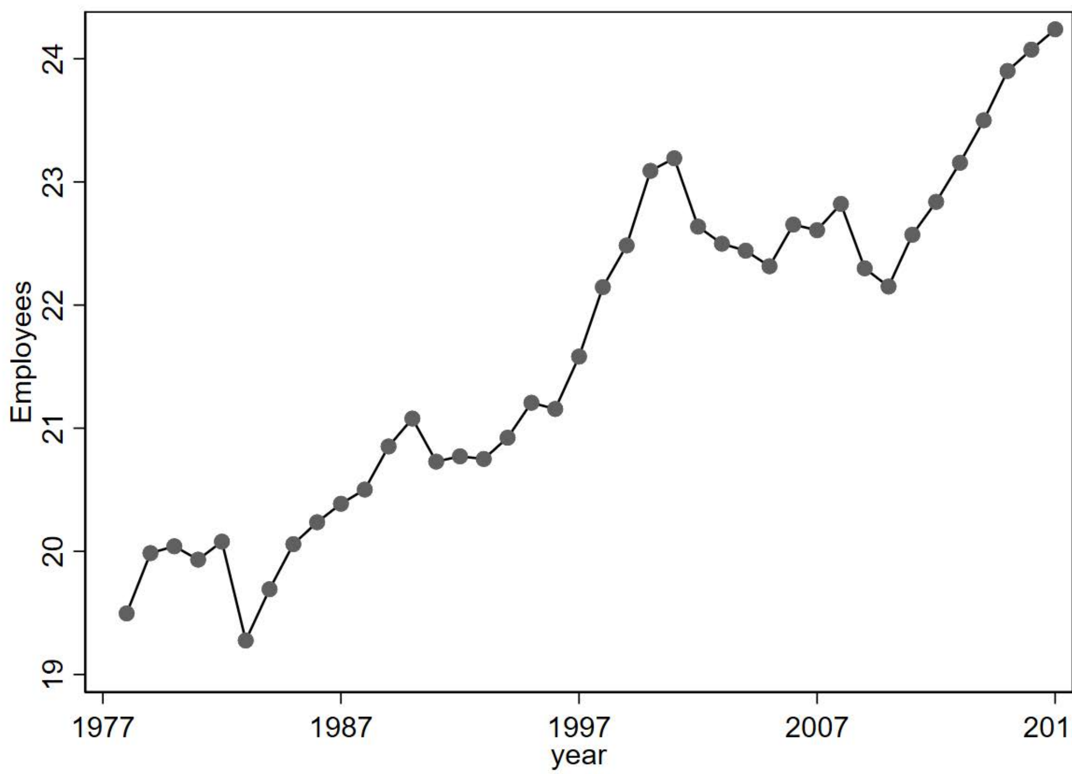
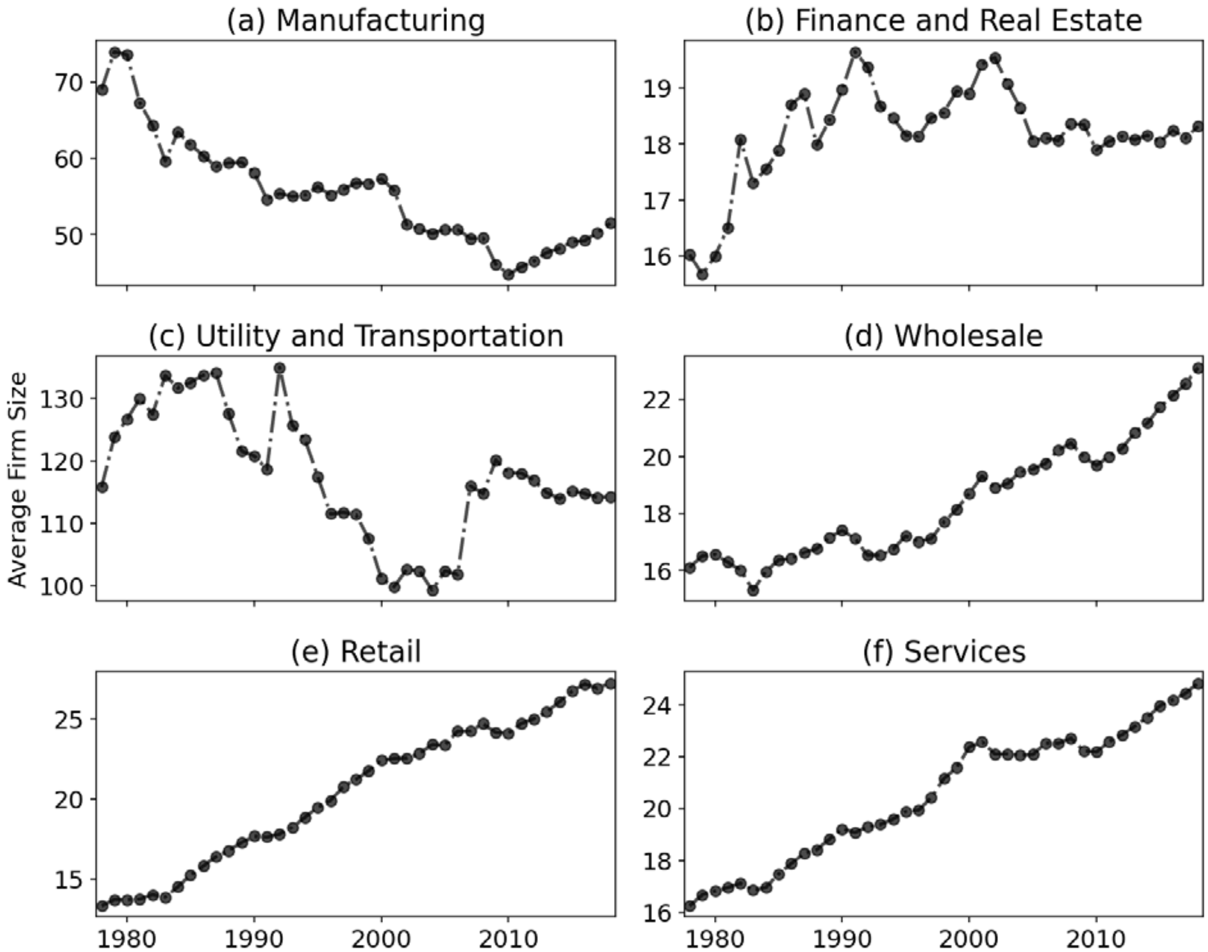


Figure 1: Average Firm Employment Size in the US (1978-2017)

Note: This figure presents the evolution of average employment of U.S. firms from 1978 to 2017. The reported statistics are based on authors' calculation using the publicly available Business Dynamics Statistics (BDS) data from the U.S. Census Bureau.



Average Firm Size Across Major Sectors

Figure 2: Average Firm Employment Size in the US (1978-2017)

Note: This figure presents the evolution of average firm employment in six major sectors. The reported statistics are based on authors' calculation using the publicly available Business Dynamics Statistics (BDS) data.

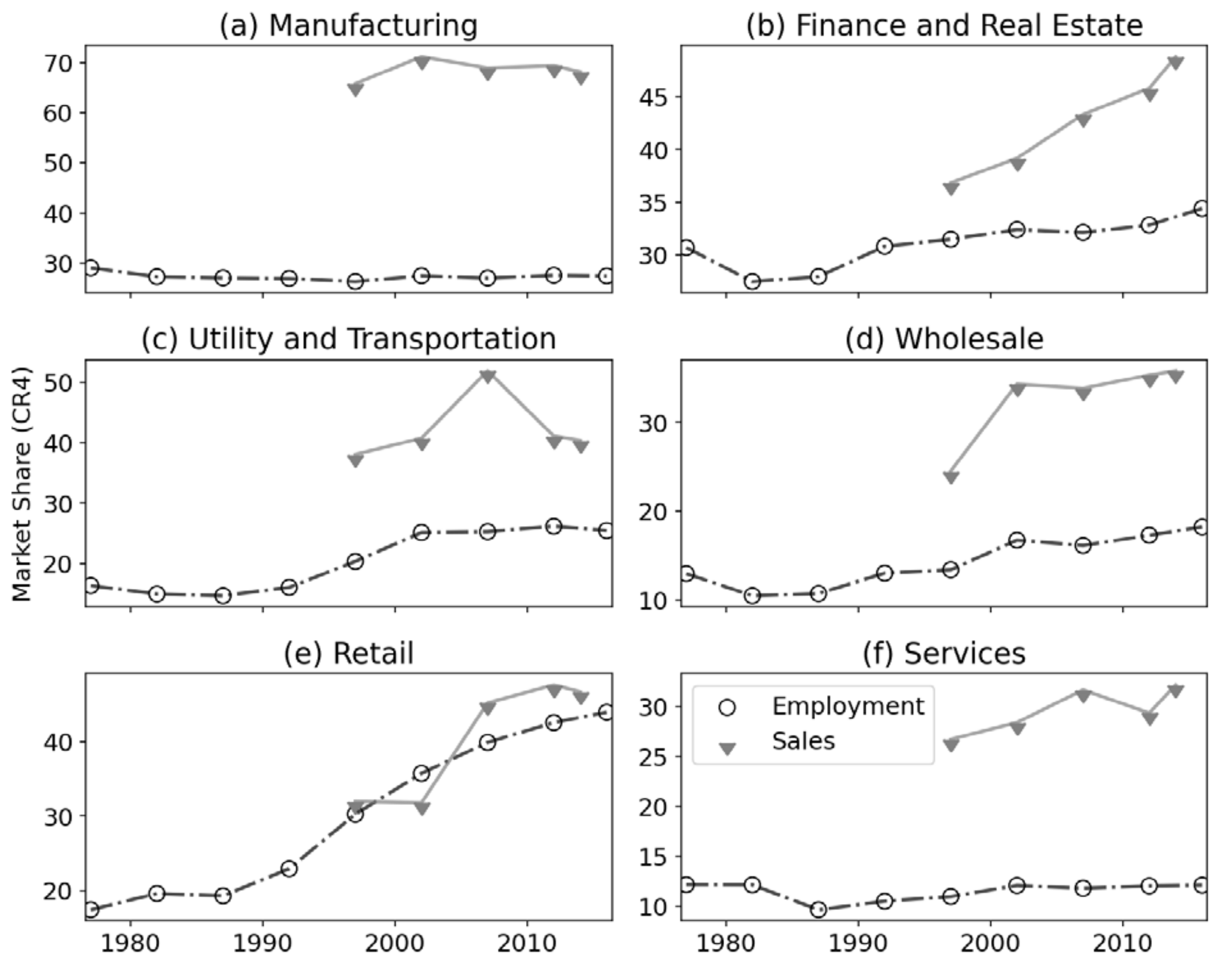


Figure 3: Employment and Sales Concentration Rates for Top 4 Firms

Note: This figure presents the weighted average concentration Rate 4 (CR4) at six digital NAICS levels in six major sectors. The reported statistics are based on the authors' calculations using the Revenue-enhanced version Longitudinal Business Database (LBDRev). The industry level CR4 is calculated by taking the shares of the four largest firms in the industry. The definition of sectors is largely derived from Autor et al. (2020). However, their paper uses time-consistent four-digit SIC codes while ours uses time-consistent six-digit NAICS codes.

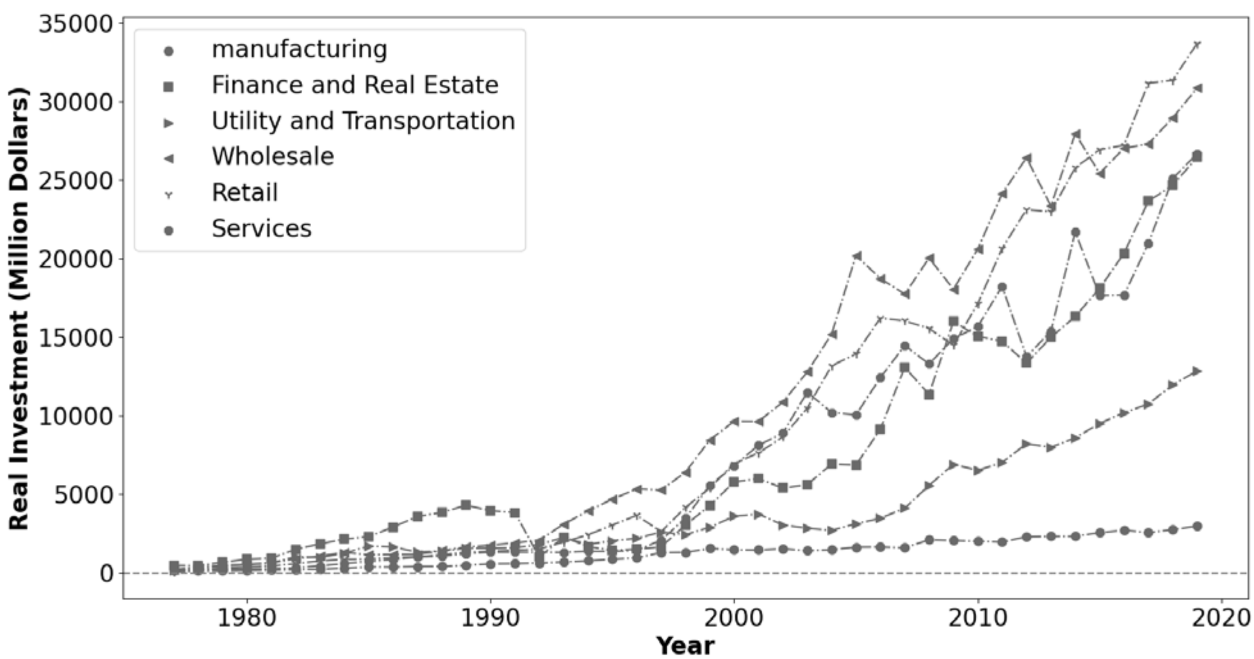
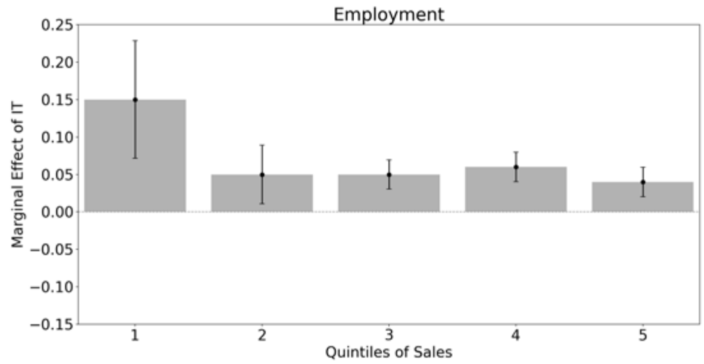


Figure 4: IT Capital Investment by Sectors

Note: This figure presents the total real IT investment in six major sectors. The reported statistics are based on the authors' calculation using investment series for private nonresidential fixed assets on all IT-related categories from the Bureau of Economic Analysis (BEA). The total IT capital investment is the sum of the capital investments for all IT equipment and software categories, including mainframes, PCs, DASDs, printers, terminals, tape drives, storage devices, system integrators, prepackaged software, custom software, and own-account software.



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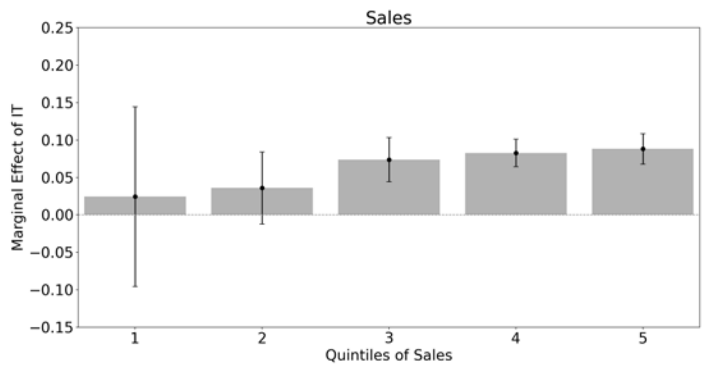

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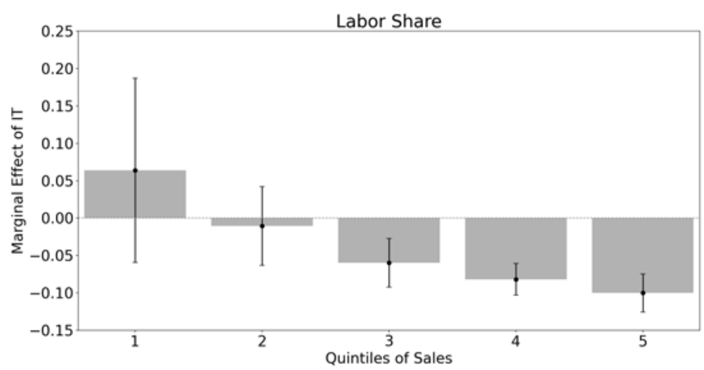


(c)

Figure 5: Heterogeneous Returns of IT Intensity on Firm Size by Size Category

Note: These figures present the estimated marginal effects of IT intensity on firm employment (Panel a), sales (Panel b), and labor share (Panel c). Quintiles are based on sales distribution. Vertical lines represent the 95% confidence intervals.

Table 1: Summary Statistics for Key Firm-level Variables

Variables	Mean	Standard Deviation	Observations
Total Employment	3,850	20,890	~50,000
Sales (M)	1,121	6,260	~50,000
IT Capital Expenditure (K)	12,680	185,600	~50,000
Total Capital Expenditure (K)	65,210	502,900	~50,000
IT Expenditure per worker (K)	6.02	201.8	~50,000
Share of Employment (%)	2.35	6.70	~50,000
Share of Sales (%)	3.43	9.84	~50,000
Labor Share (%)	0.697	6.208	~50,000
Number of establishments	77.42	404.2	~50,000
Number of zip codes	58.39	274.6	~50,000
Number of industries	4.327	5.303	~50,000

Note: Sales are in millions of dollars. Capital expenditures are in thousands of dollars. Firm's employment share is calculated as the share of the firm's employment in the total employment of the six-digit NAICS industry. Firm's sales share is calculated as the share of firm's sales in the total sales of the six-digit NAICS industry. Labor share is calculated as the ratio of payroll to sales of the firm. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules.

Table 2: IT Intensity, Firm Size, and Market Share
Baseline Results

Panel A: Employment and Employment Share

Dep.Var.	Employment (t+1)		Employment Share (t+1)	
	1	2	3	4
log(IT Intensity)	0.056***	0.050***	0.015***	0.011*
	(0.007)	(0.008)	(0.005)	(0.006)
log(Non-IT Intensity)	0.023***	0.023***	0.006**	0.002
	(0.003)	(0.003)	(0.002)	(0.003)
log(IT Intensity)(t-1)		0.025***		0.012*
		(0.008)		(0.006)
log(Non-IT Intensity)(t-1)		0.011***		0.003
		(0.003)		(0.002)
Log(Emp)	0.423***	0.368***	0.118***	0.097***
	(0.018)	(0.023)	(0.011)	(0.014)
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
R-squared	0.966	0.969	0.940	0.945
Observations	~50,000	~35,000	~50,000	~35,000

Panel B: Sales and Sales Share

Dep.Var.	Sales		Sales Share	
	1	2	3	4
log(IT Intensity)	0.101***	0.098***	0.023***	0.022***
	(0.008)	(0.008)	(0.004)	(0.004)
log(Non-IT Intensity)	0.043***	0.042***	0.010***	0.009***
	(0.004)	(0.003)	(0.002)	(0.002)
log(IT Intensity)(t-1)		0.010		-0.000
		(0.007)		(0.004)
log(Non-IT Intensity)(t-1)		0.010***		0.004***
		(0.003)		(0.002)
Log(Emp)	0.382***	0.381***	0.091***	0.090***
	(0.020)	(0.020)	(0.006)	(0.006)
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
R-squared	0.965	0.965	0.972	0.972
Observations	~50,000	~50,000	~50,000	~50,000

Note: For employment and employment share, we use the values at $t+1$ as our outcome variable because IT intensity is negatively associated with a firm's concurrent employment by construction. Firm's employment share is calculated as the share of the firm's employment in the total employment of the six-digit NAICS industry. Firm's sales share is calculated as the share of firm's sales in the total sales of the six-digit NAICS industry. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 3: IT Intensity, Firm Size, and Market Share
Robustness Checks

Panel A: Employment and Employment Share

Dep.Var.	Employment (t+1)		Employment Share (t+1)	
	1	2	3	4
log(IT Intensity)	0.053***	0.051***	0.014***	0.013**
	(0.006)	(0.007)	(0.005)	(0.005)
log(Non-IT Intensity)	0.023***	0.020***	0.006**	0.004**
	(0.003)	(0.003)	(0.002)	(0.002)
Log(Emp)	0.391***	0.402***	0.096***	0.111***
	(0.020)	(0.023)	(0.011)	(0.010)
Additional Controls	Y		Y	
Weighted		Y		Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
R-squared	0.967	0.974	0.940	0.941
Observations	~50,000	~50,000	~50,000	~50,000

Panel B: Sales and Sales Share

Dep.Var.	Sales		Sales Share	
	1	2	3	4
log(IT Intensity)	0.098***	0.098***	0.021***	0.022***
	(0.008)	(0.013)	(0.004)	(0.004)
log(Non-IT Intensity)	0.043***	0.045***	0.009***	0.009***
	(0.003)	(0.004)	(0.002)	(0.002)
Log(Emp)	0.349***	0.379***	0.071***	0.085***
	(0.022)	(0.021)	(0.006)	(0.006)
Additional Controls	Y		Y	
Weighted		Y		Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
R-squared	0.965	0.969	0.972	0.975
Observations	~50,000	~50,000	~50,000	~50,000

Note: For employment and employment share, we use the values at $t+1$ as our outcome variable because IT intensity is negatively associated with a firm's concurrent employment by construction. Firm's employment share is calculated as the share of the firm's employment in the total employment of the six-digit NAICS industry. Firm's sales share is calculated as the share of firm's sales in the total sales of the six-digit NAICS industry. Columns 1 and 3 add additional controls including the number of zip codes, number of establishments, and number of industries while columns 2 and 4 are weighted regressions using ACES sample weights. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Long-Difference Models for IT Intensity and Firm Size

Panel A: Employment (t+1)

Difference Length	1 year	2 years	3 years	4 years	5 years
log(IT Intensity)	0.0232***	0.0152**	0.0093	0.004	-0.0024
	(0.0063)	(0.0068)	(0.0075)	(0.0081)	(0.0080)
Observations	~26000	~20000	~15000	~11000	~7000

Panel B: Sales

Difference Length	1 year	2 years	3 years	4 years	5 years
log(IT Intensity)	0.043***	0.034***	0.031***	0.025**	0.024**
	(0.006)	(0.009)	(0.010)	(0.010)	(0.011)
Observations	~30000	~24000	~19000	~14000	~10000

Note: The dependent variables are one-year to five-year differences of the logarithm of the size variables, respectively. We use employment at $t + 1$ as our outcome variable because IT intensity is negatively associated with a firm's concurrent employment by construction. The independent variables are one-year to five-year differences in the logarithm of current-year IT intensity, respectively. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Instrumental Variable Models
Sedentariness

Dep.Var.	Employment (t+1)		Sales	
	1	2	3	4
log(IT Intensity)	0.002	0.007	0.645***	0.660***
	(0.006)	(0.027)	(0.043)	(0.135)
log(Non-IT Intensity)	0.017***	0.028***	0.325***	0.168***
	(0.002)	(0.007)	(0.016)	(0.037)
Log(Emp)	0.984***	0.978***	0.938***	0.927***
	(0.001)	(0.002)	(0.008)	(0.009)
1st Stage coefficient	0.928***	0.606***	0.935***	0.593***
	(0.025)	(0.051)	(0.025)	(0.051)
KP Chi-sq	968.1	140.9	966.6	132
CD Wald F	5800	384.3	5690	355.7
KP Wald F	1409	142.6	1408	133.2
Year FE	Y	Y	Y	Y
Industry FE		Y		Y
R-squared	0.954	0.945	0.674	0.692
Observations	~50,000	~50,000	~50,000	~50,000

Note: The dependent variables are identical to columns 1 and 2 of Panels A and B in Table 2. We use the share of sedentary workers at the industry level from 2000 to instrument for IT intensity. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 6: IT Intensity and Labor Share

Panel A: OLS and IV

Dep.Var.	Labor Share					
	1	2	3	4	5	6
Model	Baseline	w/ Lag	Robust	Weighted	IV (Sedentariness)	
Log(IT Intensity)	-0.095***	-0.094***	-0.094***	-0.091***	-0.100**	0.061
	(0.009)	(0.009)	(0.009)	(0.012)	(0.039)	(0.121)
Log(Non-IT Int.)	-0.031***	-0.030***	-0.031***	-0.032***	-0.282***	-0.240***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.015)	(0.034)
Log(Emp)	0.418***	0.419***	0.427***	0.420***	0.023***	0.038***
	(0.020)	(0.020)	(0.022)	(0.023)	(0.008)	(0.009)
Firm FE	Y	Y	Y	Y		
Year FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y		Y
R-squared	0.882	0.882	0.882	0.883	0.178	0.063
Observations	~50,000	~50,000	~50,000	~50,000	~50,000	~50,000

Panel B: Long Difference Models

Difference Length	1 year	2 years	3 years	4 years	5 years
log(IT Intensity)	-0.057***	-0.051***	-0.051***	-0.047***	-0.049***
	(0.008)	(0.011)	(0.013)	(0.014)	(0.016)
Observations	~30000	~24000	~19000	~14000	~10000

Note: Labor share is calculated as the ratio of payroll to sales of the firm. Column 2 in Panel A includes IT intensity and non-IT intensity from the previous year. The dependent variables in Panel B are one-year to five-year differences in the logarithm of labor share, respectively. The independent variables are one-year to five-year differences in the logarithm of current-year IT intensity, respectively. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Establishments, Zip Codes, and Industries

Panel A: Number of Establishments

	1	2	3	4
Model	Baseline	w/ Lag	IV (Sedentariness)	
log(IT Intensity)	0.0321***	0.0327***	0.1908***	0.9641***
	(0.0064)	(0.0062)	(0.0708)	(0.2800)
Log(Non-IT Int.)	0.0015	0.0019	-0.0305	-0.1922**
	(0.0021)	(0.0021)	(0.0252)	(0.0762)
Log(Emp)	0.3515***	0.3521***	0.8254***	0.8097***
	(0.0155)	(0.0156)	(0.0109)	(0.0144)
Firm FE	Y	Y		
Year FE	Y	Y	Y	Y
Industry FE	Y	Y		Y
R-squared	0.9876	0.9876	0.3514	0.3604
Observations	~50,000	~50,000	~50,000	~50,000

Panel B: Number of Zip Codes

	1	2	3	4
Model	Baseline	w/ Lag	IV (Sedentariness)	
log(IT Intensity)	0.0300***	0.0308***	0.2857***	0.7923***
	(0.0061)	(0.0059)	(0.0696)	(0.2691)
Log(Non-IT Int.)	0.0007	0.0012	-0.0632**	-0.1529**
	(0.0021)	(0.0020)	(0.0247)	(0.0732)
Log(Emp)	0.3324***	0.3329***	0.7903***	0.7908***
	(0.0153)	(0.0153)	(0.0110)	(0.0138)
Firm FE	Y	Y		
Year FE	Y	Y	Y	Y
Industry FE	Y	Y		Y
R-squared	0.988	0.988	0.3425	0.4008
Observations	~50,000	~50,000	~50,000	~50,000

Panel C: Number of Industries

	1	2	3	4
Model	Baseline	w/ Lag	IV (Sedentariness)	
log(IT Intensity)	0.0109**	0.0107***	-0.2563***	0.4255***
	(0.0043)	(0.0041)	(0.0319)	(0.1312)
Log(Non-IT Int.)	0.0051***	0.0050***	0.2024***	-0.042
	(0.0019)	(0.0018)	(0.0118)	(0.0356)
Log(Emp)	0.1428***	0.1428***	0.3626***	0.3507***
	(0.0084)	(0.0084)	(0.0064)	(0.0078)
Firm FE	Y	Y		
Year FE	Y	Y	Y	Y
Industry FE	Y	Y		Y
R-squared	0.9571	0.9571	0.2198	0.2577
Observations	~50,000	~50,000	~50,000	~50,000

Note: The dependent variables are the logarithm of the number of establishments (Panel A), zip codes (Panel B), and industries (Panel C), respectively. In each panel, column 2 also includes one-year lag of IT intensity and one-year lag of non-IT intensity as controls but are omitted in the table due to space limitations. The IV strategy (columns 3 and 4) in all panels uses the share of sedentary workers at the industry level from 2000 to instrument for IT intensity. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: IT Capital Expenditure and Industry Concentration

	1 Δ log(emp HHI)	2 Δ log(emp CR4)	3 Δ log(emp top 10%)	4 Δ log(sale HHI)	5 Δ log(sale CR4)	6 Δ log(sale top 10%)
Δ log(IT)	0.084***	0.012***	0.047***	0.080***	0.010***	0.037***
	(0.014)	(0.002)	(0.008)	(0.022)	(0.003)	(0.011)
R-squared	0.042	0.042	0.043	0.015	0.015	0.014
Observations	815	815	815	815	815	815

Note: $\Delta log(IT)$ is the difference of $log(IT)$ between 2004 and 2013. Similarly, the changes in industrial concentration are constructed based on their differences between 2004-2013. Robust standard errors are reported in parentheses;
*** p<0.01, ** p<0.05, * p<0.1.

Appendix

A.1 Skewness of Firm Employment Distribution

The evolution of firm size distribution is evident not just in average firm size but also in skewness, especially towards the right tail. Figure A1 presents the changes in the skewness of firm employment from 1987 to 2012 using micro-level census data.[25] In Trade, Transportation, Arts, Accommodation, Information and Finance, and Other service sectors, firm employment distribution is more skewed towards larger firms - a trend that suggests a more concentrated market. On the other hand, the manufacturing sector shows a declining skewness and, thus, a declining industrial concentration.[26]

A.2 Share of Top Ten Percent Firms

Following Hsieh and Rossi-Hansberg (2019), we present the evolution of the share of top 10% firms in six major sectors as an additional measure of the industrial concentration. Figure A2 shows trends similar to Figure 3 that is, Finance and Real Estate (b), Wholesale (d), Retail (e), and Services (f) sectors present an increasing share from top 10% firms. And it is true for both employment and sales. To compare with Hsieh and Rossi-Hansberg (2019), we calculate the average change of log employment share during this period and find similar results. [27]

[25]This is similar to the one presented in Benzel & Brynjolfsson (2021).

[26]Trade, Transportation, Arts, Accommodation, and Other services include sectors from NAICS 42, 44-45, 71, 72, 81; Information and Finance includes NAICS 51 and 52.

[27]In Hsieh and Rossi-Hansberg (2019), one major difference is that they calculate the share of top 10% for consistent four-digit SIC codes while we make use of six-digit FK NAICS codes. Moreover, we have both the changes in sales and employment while they focus on the change of log employment share only.

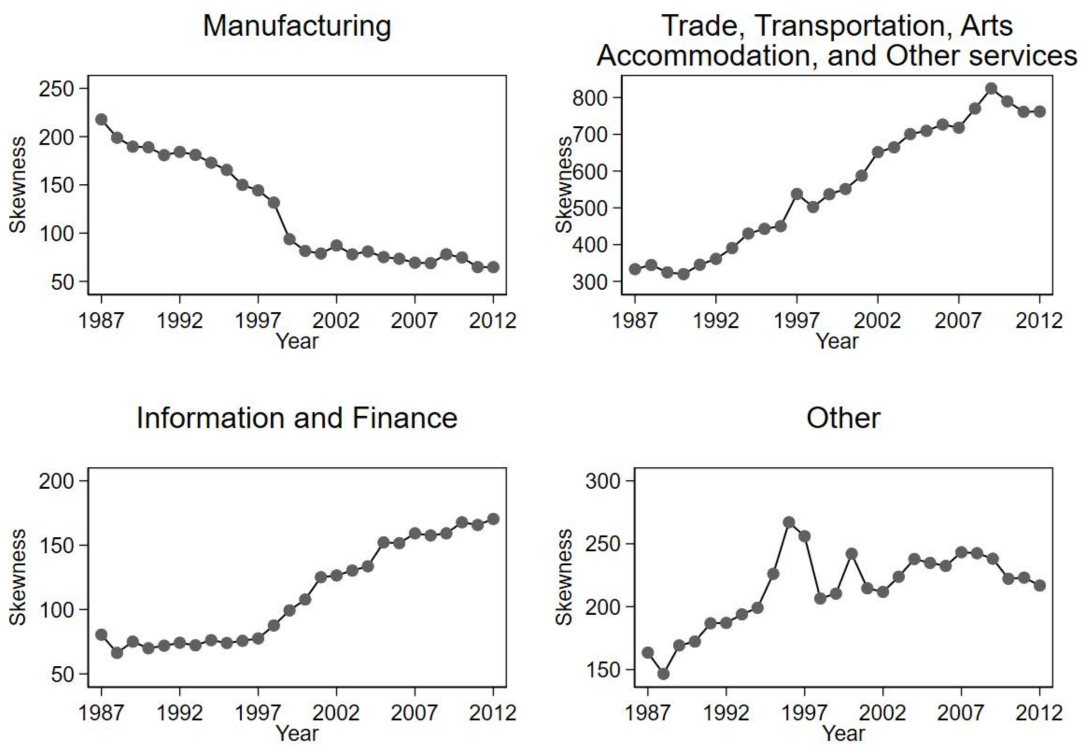
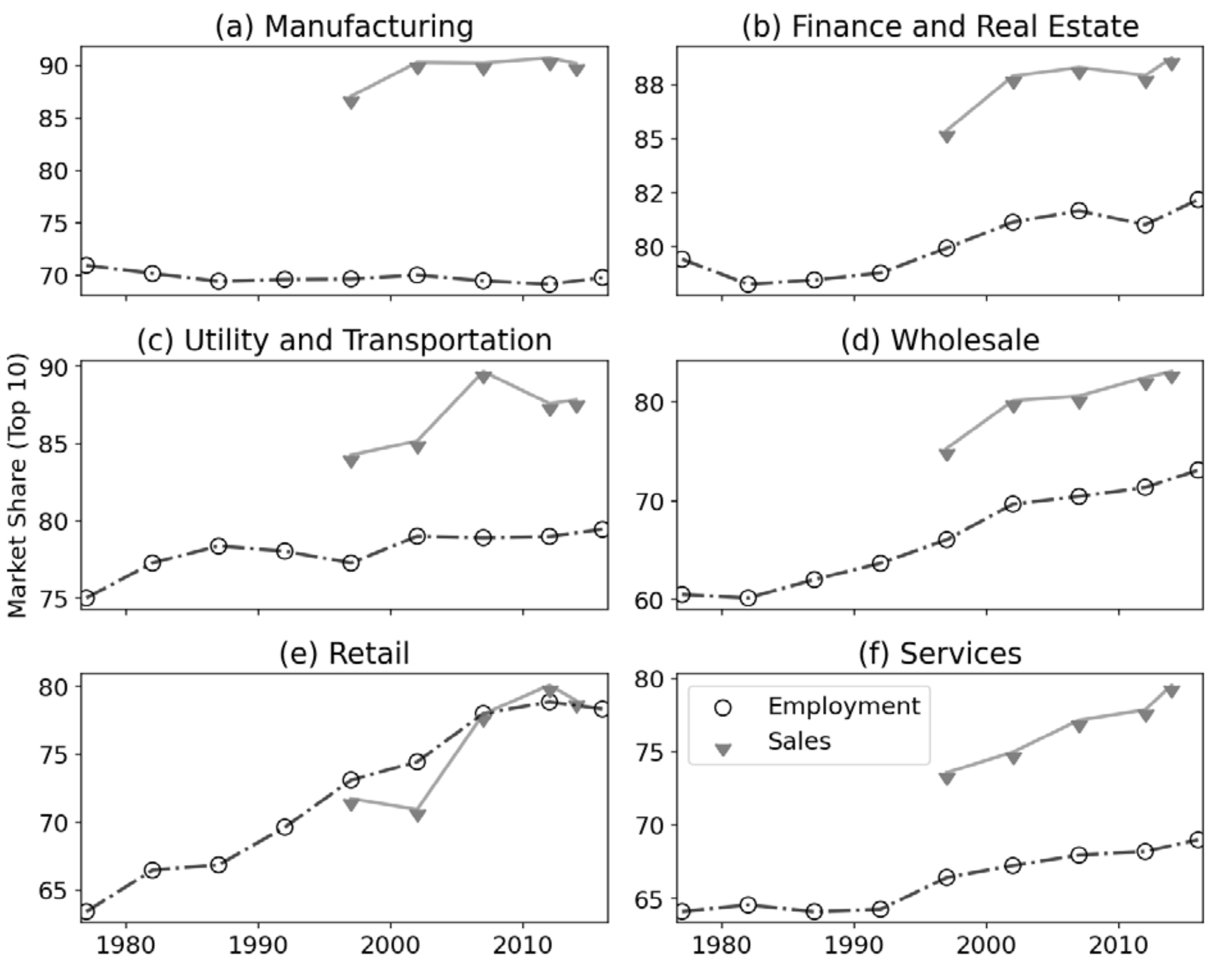


Figure A1: Skewness of Firm Employment Distribution by Major Sectors (1987-2012)

Note: Based on the Longitudinal Business Database (LBD). From Benzell & Brynjolfsson (2021). Manufacturing: NAICS 31-33; Trade, Transportation, Arts, Accommodation, and Other Services: NAICS 42, 44-45, 71, 72, 81; Information and Finance: NAICS 51, 52.



(a)

Figure A2: Employment and Sales Concentration Rates for Top 10 Percent Firms

Note: we follow a method similar to Hsieh and Rossi-Hansberg (2019) to calculate the share of the top 10% firms in each industry and take the weighted average to the sector level. The definition of sectors is consistent with the definition in Figure 3.

A.3 Key IT Measures in the ACES and ICTS

ACES Data Item Description:

- Item 2 - Total capital expenditures
- Item 5 - Capitalized Computer Software
  - Prepackaged
  - Vendor-customized
  - Internally-developed

Please see details of ACES questionnaires at:https://www.census.gov/programs-surveys/aces/technical-documentation/questionnaires.html

ICTS Data Item Description

- Item 2, Equipment Expenditures
  - 311: Computer and Peripheral Equipment
  - 313: Information and Communication Technology Equipment, Excluding Computer and Peripheral Equipment
  - 316: Electromedical and Electrotherapeutic Apparatus
- Item 3, Computer Software Expenditures
  - Capitalized Purchases and Payroll for Developing Software
  - Non-capitalized Purchases and Payroll for Developing Software

– Non-capitalized Software Licensing and Service/Maintenance Agreements

Please see details of ICTS questionnaires at:https://www.census.gov/programs-surveys/icts/technical-documentation/questionnaires.html

A.4 Alternative Instrumental Variable Specification

In addition to the instrumental variable (IV) strategy using the industry-level share of sedentary workers, we follow Barth et al. (2022) and adopt lagged IT investment from two years ago to instrument current IT investment. The results are presented in Table A1. Consistent with Table 5, IV estimations show no statistically significant correlation between IT and employment but do so with sales. Similar to Columns 3 and 4, a one percent increase in IT intensity is associated with about a 0.6 to 0.8 percent increase in sales. These results help further strengthen the causal relation between IT and sales as previously presented in Section 6.

A.5 Robustness Check with IT Expenditure

In addition to the results in Section 6, we also use IT expenditure as an alternative measure for robustness checks. We follow the empirical method in equation 1. The independent variables are the logarithm of the IT expenditures and non-IT expenditures and we report the results from these specifications in Table A2. The results show that IT expenditure is positively associated with firms' employment, sales, and their corresponding industrial shares, but negatively associated with firms' labor share. These results are broadly consistent with our main findings reported above.

Table A1: Instrumental Variable Models
Two Year Lagged IT Intensity

Dep.Var.	Employment (t+1)		Sales	
	1	2	3	4
log(IT Intensity)	-0.004	0.009	0.780***	0.643***
	(0.004)	(0.006)	(0.021)	(0.023)
log(Non-IT Intensity)	0.017***	0.025***	0.282***	0.168***
	(0.002)	(0.002)	(0.011)	(0.009)
Log(Emp)	0.985***	0.979***	0.952***	0.942***
	(0.002)	(0.002)	(0.009)	(0.008)
1st Stage coefficient	0.818***	0.748***	0.772***	0.682***
	(0.007)	(0.008)	(0.008)	(0.010)
KP Chi-sq	718.4	645.8	703.6	621.2
CD Wald F	69180	43960	46970	28210
KP Wald F	15840	8653	8758	5053
Year FE	Y	Y	Y	Y
Industry FE		Y		Y
R-squared	0.956	0.949	0.679	0.705
Observations	~35,000	~35,000	~35,000	~35,000

Note: We use lagged IT investment from two years ago to instrument current IT investment. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

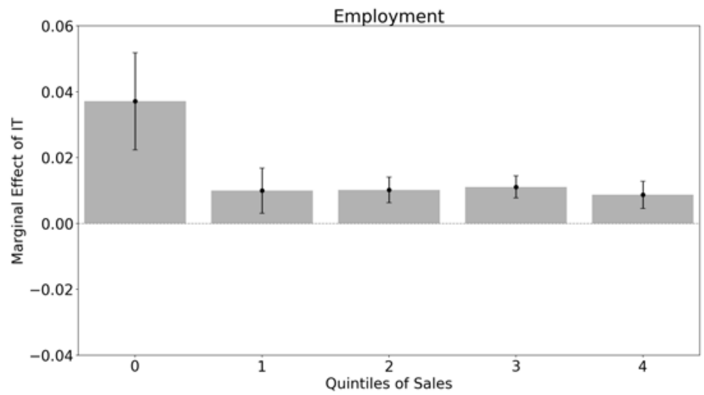
Table A2: IT Expenditure, Firm Size, Market Share, and Labor Share

Dep.Var.	Employment (t+1)		Employment Share (t+1)		Sales		Sales Share		Labor Share	
	1	2	3	4	5	6	7	8	9	10
log(IT Expnd)	0.0117***	0.0099***	0.0032***	0.0023*	0.0167***	0.0149***	0.0033***	0.0028***	-0.0102***	-0.0088***
	(0.0013)	(0.0015)	(0.0009)	(0.0012)	(0.0021)	(0.0020)	(0.0008)	(0.0008)	(0.0021)	(0.0020)
log(Other Expnd)		0.0069***		0.0023**		0.0104***		0.0019**		-0.0072***
		(0.0015)		(0.0011)		(0.0023)		(0.0008)		(0.0023)
log(IT Expnd)(t-1)	0.0121***	0.0114***	0.0032***	0.0023*	0.0199***	0.0191***	0.0048***	0.0046***	-0.0125***	-0.0120***
	(0.0015)	(0.0016)	(0.0011)	(0.0012)	(0.0020)	(0.0020)	(0.0008)	(0.0008)	(0.0020)	(0.0020)
log(Other Expnd)(t-1)		0.0045***		0		0.0123***		0.0042***		-0.0094***
		(0.0015)		(0.0010)		(0.0020)		(0.0008)		(0.0020)
Log(Emp)	0.3804***	0.3244***	0.1062***	0.0889***	0.3070***	0.2990***	0.0741***	0.0719***	0.4795***	0.4854***
	(0.0196)	(0.0256)	(0.0113)	(0.0155)	(0.0199)	(0.0197)	(0.0063)	(0.0062)	(0.0229)	(0.0229)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
R-squared	0.9663	0.9688	0.9394	0.9446	0.9643	0.9644	0.9722	0.9722	0.8808	0.881
Observations	~50,000	~35,000	~50,000	~35,000	~50,000	~50,000	~50,000	~50,000	~50,000	~50,000

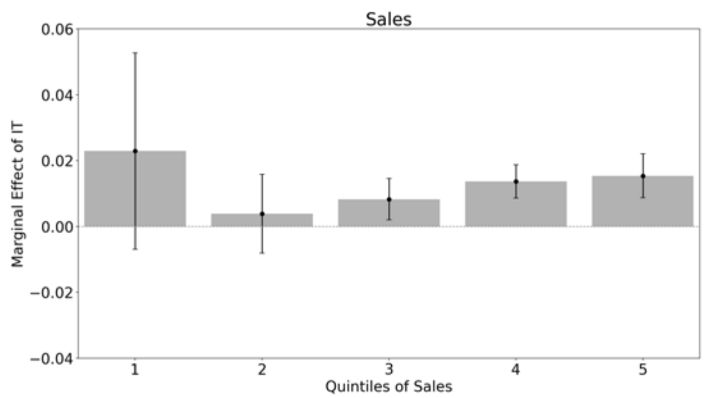
Note: The independent variables are the logarithm of the IT expenditures and non-IT expenditures. Firm's employment share is calculated as the share of the firm's employment in the total employment of the six-digit NAICS industry. Firm's sales share is calculated as the share of firm's sales in the total sales of the six-digit NAICS industry. Labor share is calculated as the ratio of payroll to sales of the firm. The number of observations is rounded to the nearest thousand, in accordance with Census Bureau disclosure rules. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Heterogeneous Effects of IT Expenditure on Firm Size by Size Category

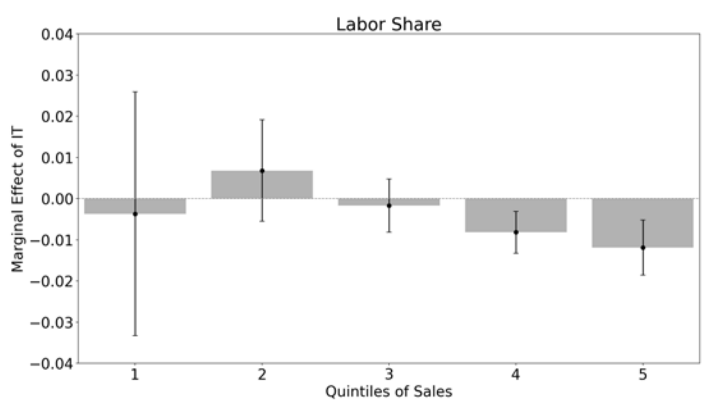
Similar to Figure 5, we follow equation 2 in section 5 and explore the effect heterogeneity of IT expenditure (instead of IT intensity) for different sized firms for an additional robustness check. The marginal effects of IT expenditure on employment, sales, and labor share are plotted in Figure A3 Panel (a), (b), and (c), respectively. The results are largely consistent with Figure 5 and provide additional supporting evidence that investment in IT is associated with a faster growth of employment and sales, and a faster decline of labor share for larger firms, which then further suggest that IT contributes to the growing industrial concentration.



(a)



(b)



(c)

Figure A3: Heterogeneous Returns of IT Expenditure on Firm Size by Size Category

Note: This figure presents the estimated marginal effects of IT expenditure on firm employment (Panel a), sales (Panel b), and labor share (Panel c). Quintiles are based on sales distribution. Vertical lines represent the 95% confidence intervals.