Flattening Hierarchies or Amplifying Control? How Frontier Technologies (Re)Shape (De)Centralization within Organizations.

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The authors declare that they have no relevant financial interests or personal relationships that could have appeared to influence the work reported in this paper. All views expressed are those of the authors and do not necessarily reflect the views of the NBER. This study uses data from the IAB Establishment Panel. Data access was provided through on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB), followed by remote data access.

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Abstract

Decentralization - the delegation of decision-making authority to lower levels of the organizational hierarchy - is central to harnessing benefits of comparative advantage through specialization. While prior cross-sectional studies suggest that Information and Communication Technology (ICT) investments affect worker autonomy and span of control, the direction of causality remains uncertain: does technology reshape organizational structure, or does organizational structure determine how technology is used? Our paper investigates the evolving relationship between ICT and decentralization, with a focus on maturity and investments in technology over time and organizational context. Using a panel dataset of 28,691 German establishments (1998–2021), we find robust evidence that ICT investments lead to sustained increase in decentralization over time. However, this effect is smaller than prior literature reported once establishment-level fixed effects are accounted for. Notably, the positive effect weakens over time within a firm, indicating that earlier technology investments reshape workplaces and (de)centralization but frontier technology investments may continue to do so at a decreasing rate and may also have possibility in future of (re)centralizing organizations. Moreover, we find although larger firms are likely to be more decentralized, digital technologies are more likely to sustain decentralization in smaller firms relative to megafirms, challenging the assumption that ICT uniformly shifts authority downward. We conclude a nuanced relationship in which technologies can both decentralize and recentralize decision-making, depending on their use, maturity, and organizational context.

1. Introduction

Do information and communication technologies (hereafter: ICTs) shift decision-making authority from managers to non-managerial employees, or do they reinforce managerial control? Recent years have witnessed growing interest in how technological change reshapes organizations. Decentralization—the delegation of decision-making authorities to lower levels of the organizational hierarchy—plays a critical role in leveraging dispersed knowledge, communication efficiencies, and comparative advantage. While prior cross-sectional studies suggest that ICT investments affect worker autonomy and managerial span of control, the direction of causality remains unclear: does technology reshape organizational structure, or do pre-existing organizational structures determine how technology is used?

This paper investigates the evolving relationship between ICT and decentralization, focusing on the timing and persistence of ICT effects, the maturity of technology, and heterogeneity across firm types. We use a rich panel dataset of 28,691 German establishments from the Institute of Employment Research (IAB) Establishment Panel (1998–2021), one of the longest-running employer surveys globally. Our empirical strategy combines lagged regressors with establishment fixed effects to isolate within-firm changes and address concerns about simultaneity and unobserved heterogeneity.

Our results show that ICT investments are associated with a sustained increase in decentralization. However, this effect is smaller than prior literature suggests once establishment-level fixed effects are accounted for. We find that the effect is stronger when ICT investment is lagged—particularly one year prior—highlighting a delayed response likely due to the time required for technology integration and organizational adaptation. In our preferred model specification, cumulative ICT investments over the three prior years are associated with a 5.4 percentage point higher likelihood of decentralization, relative to firms with no investment history in the past three years.

Importantly, we find that the marginal effect of ICT on decentralization weakens over time: ICT investments in the 2010s have less decentralizing power than those in the late 1990s or early 2000s. These patterns suggest diminishing returns to digital technologies for flattening hierarchies—or, conversely, that recent ICT tools are increasingly used to support managerial oversight and control. Moreover, while smaller firms exhibit more consistent decentralization in response to ICT investments, we find little systematic evidence that larger firms or "megafirms" experience stronger or more durable decentralizing effects with ICT, even though larger firms on average are more decentralized. Initial post-investment responses in large firms are somewhat larger, but these quickly attenuate and are not statistically robust over time.

This paper makes three main contributions. It is one of the first longitudinal, establishment-level evidence on how ICT investments reshape internal hierarchies over time. By leveraging panel data and fixed effects, we address long-standing concerns about selection and unobserved firm heterogeneity that limit inference from cross-sectional studies. Second, we uncover important temporal dynamics in ICT's organizational effects. Our analysis shows that decentralization effects are strongest shortly after adoption but weaken in later years, especially for more recent ICT cohorts—offering novel insight into the time-varying nature of digital transformation and different types of technologies. Third, we add to the literature on organizational heterogeneity by showing that firm size significantly moderates ICT's effects. Contrary to the hypothesis that ICT empowers decentralization more strongly in large, complex firms, we find that small and mid-sized establishments respond more consistently suggesting that digital tools may amplify or have no effect, rather than flatten, existing hierarchies in megafirms.

The remainder of the paper is structured as follows. Section 2 discusses the theoretical background and hypotheses. Section 3 describes the data, key variables, and empirical strategy.

Section 4 presents our main results and heterogeneous effects. Section 5 discusses implications and mechanisms. Section 6 concludes.

2. Background and Hypotheses Development

2.1 ICT as a Driver of Decentralization

Garicano's (2000) *Knowledge-Based Hierarchies* (hereafter: KBH) model conceptualizes organizations as hierarchical systems for efficient information processing and problem-solving. Its core assumptions are heterogeneous knowledge, problem solving, and cost-tradeoffs. That is to say that employees and managers possess disparate expertise, and skills are distributed across hierarchical levels. Employees address routine issues independently using their own knowledge, while complex—exceptional—problems escalate to managers with greater expertise. Within this framework, decentralization—the delegation of decision-making authority to lower levels of the organizational hierarchy—emerges as a rational response to minimize two key costs: information acquisition costs (e.g., training lower-level workers to handle more complex tasks) and communication costs (e.g., escalating unsolved problems to higher-level managers).

ICT plays a central role in this cost calculus where KBH model offers a nuanced prediction:

- When ICT lowers information acquisition costs (by giving employees direct access to knowledge, databases, or analytics), it can enable decentralization by allowing lower-level workers to solve a broader set of problems independently.
- Conversely, when ICT lowers communication costs (by improving upward reporting, dashboards, or real-time supervision), it can reinforce centralization, as it becomes less costly for higher-level managers to remain directly involved in decision-making.

This dual mechanism implies that the organizational consequences of ICT are not uniform and depend on which frictions the technology alleviates most (Bloom et al., 2014).

Despite this theoretical ambiguity, early empirical studies largely emphasize ICT's decentralizing effects, particularly through the information-acquisition channel. For example, Garicano and Wu (2012) provide direct support for this mechanism: they show that ICT adoption allows employees to handle a greater variety of tasks by giving employees direct access to information reducing the need for managerial oversight and reducing information acquisition costs, effectively flattening organizational hierarchies and reducing the need for costly escalation.

Acemoglu et al. (2007) offer a related but distinct mechanism rooted in a principal-agent perspective. They argue that decentralization arises from firms' desire to leverage localized knowledge in environments with uncertainty and information scarcity. During the 1990s, frontier firms increasingly delegated authority in order to adapt more quickly to local market conditions—particularly when ICT helped them coordinate and learn across units. Here, ICT's role was to enable better learning and adaptation, not merely internal efficiency.

Bresnahan et al. (2002) identify yet another pathway: they observe that ICT investments often coincide with complementary organizational changes such as team-based work, job redesign, and flatter hierarchies. In this view, decentralization is part of a broader bundle of workplace transformations enabled by ICT, rather than a direct consequence of technology alone.

Taken together, these studies highlight that ICT can support decentralization via multiple, complementary channels—by empowering employees with direct access to information, by facilitating responsiveness to local conditions, and by enabling new organizational forms. Notably, most of this literature focuses on ICT as a tool for distributing decision-making authority, with less emphasis on cases where ICT may reinforce central control.

This leads to our first hypothesis:

Hypothesis 1: Investment in ICT leads to a sustained increase in the **decentralization** of decision-making authority within organizations over time.

2.2 Firm Size and Decentralization

While the KBH framework highlights how ICT affects decentralization through its impact on information-processing and communication costs, the role of firm size in this dynamic remains underexplored (Garicano, 2000). As organizations grow, they tend to develop deeper hierarchies, longer chains of command, and greater internal complexity. This expansion amplifies both the difficulty of transmitting information upward and the value of knowledge held by frontline employees. In such settings, ICT that reduces information-processing costs—by empowering employees with access to knowledge and tools—can enable decentralization by allowing local actors to solve a wider range of problems without escalation.

Conversely, if ICT primarily lowers communication costs, as in the case of real-time monitoring or centralized reporting systems, it may reinforce centralization. Managers can remain more involved in decision-making without being overwhelmed by coordination burdens. Thus, whether ICT leads to decentralization depends not only on the type of technological intervention but also on how the firm's scale amplifies or dampens the need for localized autonomy.

In smaller firms, this calculus differs. Knowledge is more concentrated, communication chains are shorter, and decision-making authority is already proximate to execution. As a result, the marginal benefits of decentralization via ICT may be limited. With flatter structures and lower coordination costs, small firms may see little incentive—or even counterproductive complexity—in distributing authority further.

Acemoglu et al. (2007) offer a complementary perspective. While their model is rooted in a principal-agent framework and focuses on the trade-offs between delegation and learning under uncertainty or information scarcity. Although not explicitly about firm size, many of their mechanisms—such as the ability to delegate, absorb knowledge, and—scale with organizational size. Larger firms often enjoy informational advantages and broader capacity to learn from decentralized experimentation but also face higher agency costs. These tensions mean that the ability of large firms to decentralize depends in part on how effectively ICT can reduce coordination and monitoring costs.

The moderating role of firm size is thus essential in understanding how ICT adoption influences organizational structure. ICT investments have the potential to reduce information-processing costs, facilitate monitoring, and streamline communication channels—effects that may be particularly valuable in large firms, where such costs are otherwise prohibitive. By contrast, smaller firms, which already operate with flatter hierarchies and more centralized control, may see limited marginal benefit from ICT-enabled decentralization especially related to communication and monitoring.

This distinction is increasingly salient in light of recent empirical findings on the rise of large-scale firms (megafirms) in the digital economy. Hsieh & Rossi-Hansberg (2023) document the rise of large service-sector firms that expand via ICT-intensive, fixed-cost strategies. Yet it remains unclear whether decentralization plays a central role in sustaining such scale, or whether success stems more from cost leverage, access to capital, or market power. Similarly, Kwon et al. (2024) highlight rising firm concentration—especially in digital-intensive sectors—without fully disentangling the internal organizational adjustments that support it. Braguinsky et al. (2023) further suggests recent resurgence of mega firms in

innovation, but whether they restructure decision-making hierarchies alongside technological investments is an open question.

Taken together, these theoretical and empirical insights suggest that firm size could moderate the organizational impact of ICT. Particularly for large firms, ICT may serve as a critical enabler of decentralization by lowering costs of information processing and monitoring. This leads to our second hypothesis:

Hypothesis 2: The effect of ICT investments on decentralization of decision-making authority is **stronger** when organizations are larger in size, relative to when they are smaller.

2.3 Maturity of ICT Effects Over Time

While early ICT investments were associated with decentralization, the cost perspective of KBH refutes ICT as a unidirectional force that uniformly empowers lower-level employees. The capacity of ICT to disseminate information downward is only one side of the equation. As digital technologies advance, they increasingly support centralized oversight by lower communication costs and enabling real-time data collection, algorithmic monitoring, and decision enforcement. This dual nature complicates the narrative, suggesting that ICT can both distribute and consolidate authority—depending not just on its type, but on its maturity, implementation, and managerial use.

Bloom et al. (2014) contribute to this discussion by distinguishing between information technologies, which tend to foster decentralization, and communication technologies, which may create centralization patterns across organizations. Their analysis, based on cross-sectional data from the early 2000s, builds on prior research on ICT investments and organizational economics(Acemoglu et al., 2007; Bloom, Sadun, & Van Reenen, 2012; Bresnahan et al., 2002; Garicano & Heaton, 2010). However, the cross-sectional nature of Bloom et al. (2014)'s study

introduces important limitations. By focusing on early-generation technologies such as intranets and Enterprise Resource Planning (ERP) systems, their analysis presents a snapshot of ICT's organizational that does not capture the longitudinal evolution technologies or the dynamic relationship between ICT and decision-making authority. As digital infrastructures continue to evolve—incorporating tools like real-time collaboration platforms, cloud computing, and AI-driven decision support—the boundaries between decentralization and centralization are likely to shift, warranting longitudinal approaches that better capture these technological developments *over* time and *within* organizations.

This temporal dynamic intersects with insights from the literature on skill-biased technological change (hereafter: SBTC). SBTC posits that technological advancements disproportionately increase demand for high-skilled workers performing non-routine cognitive tasks while displacing routine manual roles(Autor et al., 1998, 2003; Machin & Van Reenen, 1998; Michaels et al., 2014). While SBTC primarily focuses on labor market polarization and occupational shifts, how the logic extends to intra-organizational hierarchies through task displacement and creation is not clear (Autor et al., 2024). In particular, the implications of ICT-induced changes in task composition for the delegation of decision-making authority from managers to employees remain insufficiently explored. This opens important questions about how evolving task structures mediate organizational hierarchies in the digital age.

Building on these insights, frontier technologies—particularly artificial intelligence (hereafter: AI)—introduce new dimensions to this discussion, further reshaping organizational decision-making authority. Bloom et al. (2014), predate the rise of AI and therefore cannot fully account for how contemporary ICT continues to reshape organizational structures. AI represents a frontier form of ICT, transforming information acquisition by simulating human cognitive processes and operating (semi-)autonomously – surpassing earlier technologies in both scope and function. Unlike traditional systems, AI can independently gather, process, and disseminate

information— tasks once reserved for mid- and upper-level employees(Ide & Talamas, 2024; Kellogg et al., 2020).

These capabilities have enabled the rise of algorithmic management—a system in which AI tools govern workflows, assign tasks, evaluate performance, and enforce compliance(Baiocco et al., 2022; Wood, 2021) which alter the balance between decentralization and centralization. Initially, ICT lowered the cost of information access, enabling employees at lower hierarchical levels to make more independent decisions (Garicano & Wu, 2012). However, with the integration of AI and frontier technologies, the emphasis is shifting toward enhanced managerial oversight and control. AI systems do not merely distribute information—they also communicate insights upward, enforce protocols, and automate monitoring functions. This shift lowers the need for human-mediated communication and communication costs while increasing top-down visibility and coordination, effectively recentralizing decision-making authority. In this new technological configuration, communication and control capacities increasingly outweigh the decentralizing effects of information access, leading to a more complex and potentially hierarchical organizational structure.(Baiocco et al., 2022; Wood, 2021).

Given this incremental evolution of ICT's role in information acquisition and communication capabilities and decision-making, we propose the following hypothesis:

Hypothesis 3: The effect of ICT investments on decentralization of decision-making authority has **weakened** over time.

3. Data and Method

3.1. Data

3.1.1. Data Source and Sample

For our analyses, we use high-quality panel data from the Institute for Employment Research (IAB) Establishment Panel, a long-running and representative annual survey of establishments in Germany (Bächmann et al., 2022).The panel is administered by the Institute for Employment Research (IAB) at the German Federal Employment Agency in Nuremberg. It includes approximately 15,000 to 16,000 establishments per year and covers the period 1993 to 2021, drawn from a population of about 2 million German employers. West German establishments have been surveyed since 1993 and East German establishments since 1996.

The IAB Establishment Panel surveys a stratified random sample of establishments across all industries and establishment size classes, covering firms with at least one employee subject to social security contributions, referenced to June 30 of each year. The sample covers about 1% of all German firms and approximately 7% of all employment, making it uniquely suited to studying organizational structures and technological change. Data are collected through structured personal interviews with management-level personnel and include rich information on establishment characteristics such as employment, turnover, sector, investment activities, and organizational practices.

We use data provided through the German Research Data Centre (FDZ) under strict confidentiality agreements. For our study, we construct a panel of establishments observed over multiple years and apply the following sample restrictions:

- The dependent variable—downward decentralization of responsibilities—must be observed (available from 1995 onward).

- Valid lag structures for ICT investment (up to four consecutive years) must be available, based on data beginning in 1993.
- Establishments must be observed in at least three different years to allow for within-establishment variation and the inclusion of establishment fixed effects (hereafter: we use "establishment" and "firm" interchangeably).

To ensure comparability across specifications, all regressions are estimated on a harmonized sample with consistent coverage of industries, years, and firm characteristics. Our final analytic sample includes approximately 28,691 establishments and 90,801 observations, depending on model specification, covering the years 1998 to 2021.Furthermore, we retain distinct industry identifiers based on three business register vintages (1993–1999, 2000–2008, 2009–2021) when using industry fixed effects.

To contextualize the empirical analyses that follow, we begin by presenting summary statistics and descriptive trends for the key variables in our study. Table 1 displays the descriptive statistics for the pooled establishment-year sample, including measures of decentralization, ICT investment, and firm size. On average, 11% of establishments experienced a downward shift in decision-making authority, while 43% reported making ICT investments.

Figure 1 complements this overview by illustrating the temporal evolution of ICT investment and decentralization from 1998 to 2021, shedding light on how the relationship between digital investment and organizational authority structures has changed over time. In 1998, only 36% of establishments reported ICT investments, a figure that rose sharply to 64% by 2021. In contrast, the prevalence of decentralized decision-making declined markedly over the same period—from 29% in 1998 to just 7% in 2021 highlighting a divergence between

technological investment and the distribution of decision-making authority within firms over time.

Table 1: Descriptive statistics for pooled establishment-years

Variable	N	Mean	SD	Min	Max
Decentralization	90,801	0.11	0,32	0	1
ICT investment	90,801	0.43	0,49	0	1
Ln (Firm Size)	90,801	3.13	1,84	0	11.02

Notes: This table presents descriptive statistics for the pooled sample of 90,801 establishment-year observations from 1998 to 2021. ICT investment is a binary variable equal to 1 if the establishment reported operational investments in Electronic Data Processing (EDP) or Information and Communication Technologies (ICTs) in the previous business year, and 0 otherwise. Decentralization is a binary indicator equal to 1 if decision-making responsibilities were delegated downward within the organizational hierarchy, and 0 otherwise. Ln (Firm Size) refers to the natural logarithm of the number of employees in June of each business year.

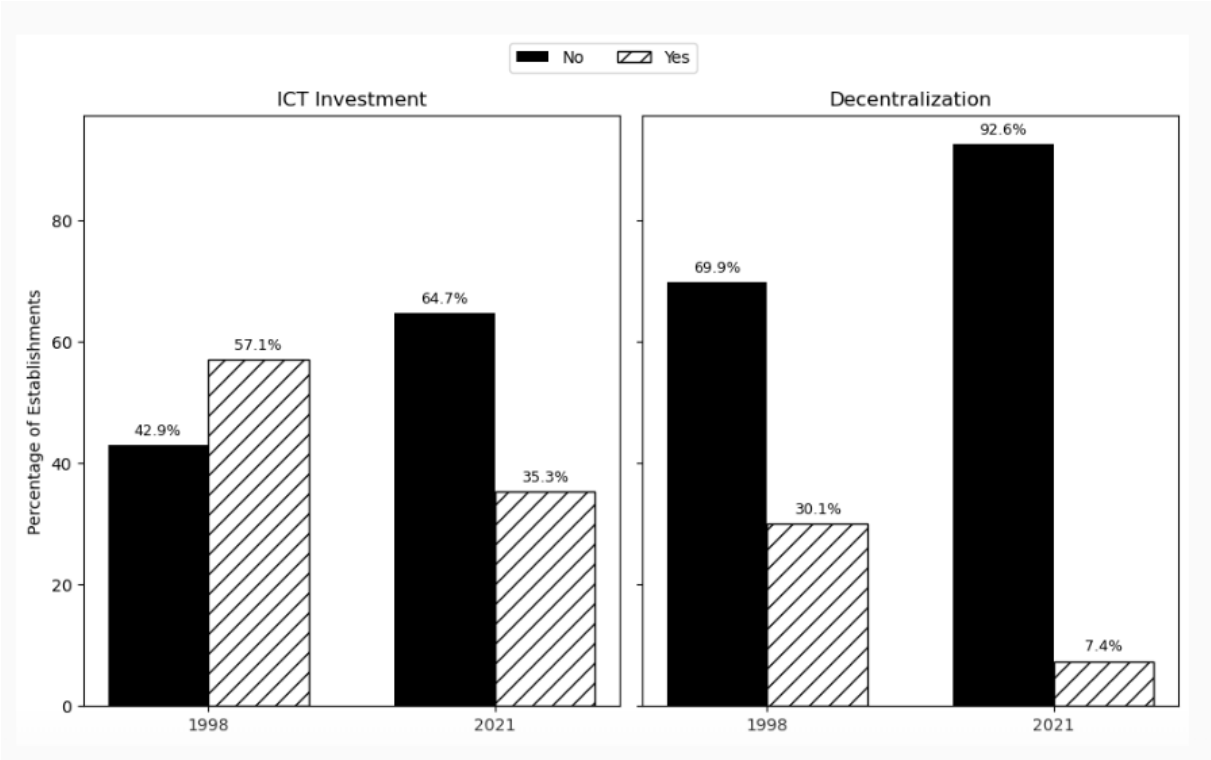


Figure 1: Changes in ICT investments and Decentralization (1998 vs 2021)

Notes: The bars display the percentage of establishments of the total establishments observed reporting either ICT investment in the previous business year or decentralized decision-making (i.e., downward delegation of authority) in the beginning and end of panel namely, in 1998 and 2021. ICT investment equals 1 if the establishment reports operational investments in Electronic Data Processing (EDP) or Information and Communication Technologies (ICTs) in the previous business, and 0 otherwise, while decentralization is a binary indicator equal to 1 if decision-making responsibilities shifted downward within the organizational hierarchy (i.e., decentralization), and 0 otherwise. In

1998, 2,347 establishments were observed; in 2021, 6,659 establishments were observed. Hatched white bars refer to yes; solid black bars refer to no for indicator values of ICT investment and decentralization, respectively.

3.1.2. Dependent Variable.

We capture decentralization using three establishment survey questions that assess whether decision-making authority is delegated from upper to lower levels of employees within a firm. Specifically, we consider: (i) whether responsibilities and decisions are generally shifted downward within the organization, (ii) whether there is an introduction of units with their own financial responsibility through cost and result calculations, and (iii) whether teams or working groups are introduced that operate autonomously with their own responsibilities. The dependent variable (decentralization)—which changes relatively slowly over time—is observed at intervals of approximately every 2–3 years from 1995 to 2021.

To capture decentralization, we use the first measure as our primary construct, as it directly reflects delegation of authority from higher to lower levels, signifying worker autonomy as in Bloom et al. (2014). Additionally, for robustness test and based on prior literature we use profit or cost center organization(Acemoglu et al., 2007) and self-managing teams with their own responsibilities (Bresnahan et al., 2002) as relevant dimensions, to ensure consistency.

3.1.3 Independent variable

In contrast to the dependent variable, the independent variable is recorded annually for all establishments between 1993-2021. We capture ICT investment based on a binary indicator in the establishment survey on whether the company has made operational investments in electronic data processing (EDP) and information and communication technologies (ICTs) in the previous business year.

Although our measure does not allow for continuous variation ICT (hardware) investments unlike some earlier studies which consider the Harte-Hanks Technology database(

e.g. Acemoglu et al., 2007; Bloom et al., 2014; Bloom, Sadun, & Reenen, 2012; Bresnahan et al., 2002; Garicano & Heaton, 2010), it has several strengths. The Harte-Hanks Technology database primarily focuses on hardware infrastructure investments, neglecting a broader range of technological advancements, and are constrained by shorter time spans and data from periods predominantly before the early 2000s. In contrast, our measure captures broader aspects of ICT adoption and a consistent perspective that spans a rich panel nearly three decades 1993–2021. This extended time coverage allows for a more comprehensive analysis of the long-term impact of ICT *within* organizations, balancing data availability and conceptual relevance.

3.1.4 Controls and Moderator

The primary controls that we consider are firm size (measures such as the log of the number of employees), industry fixed effects and year fixed effects. A key feature of our data is that it is longitudinal, enabling us to add establishment fixed effects to control for unobserved time-invariant firm heterogeneity. In robustness analyses, we also introduce a broader set of time-varying control variables.

While we acknowledge the potential relevance of additional organizational characteristics, our baseline model deliberately focuses on firm size for three key reasons. First, we exclude other variables from the core specification due to concerns about endogeneity; many of these characteristics are likely influenced by ICT investment itself, making them "bad controls" that can introduce included variable bias (Angrist & Pischke, 2009; Cinelli et al., 2024). To avoid compromising causal inference, we reserve these controls for robustness checks rather than the main model. Second, unlike prior cross-sectional studies, our use of establishment-level fixed effects allows us to account for firm heterogeneity directly. Including additional controls in this context risks inflating multicollinearity and obscuring the true relationship between ICT and decentralization. Third, this approach helps preserve larger sample consistency by minimizing attrition due to missing covariates. For robustness, we

supplement the baseline model with commonly used controls—such as firm age, skill intensity, and organizational form—and find that the core results remain stable. These variables[5] exert only marginal influence on the ICT-decentralization relationship, particularly once fixed effects are accounted for.

3.2 Method

We base our analysis on a rich panel dataset spanning 28 years, from 1993 to 2021. Although the dependent variable is measured intermittently, the independent variable—ICT investment—is tracked annually, enabling us to construct lagged measures and introduce meaningful temporal structure into the analysis. Regression models are estimated only for the years in which the dependent variable is observed, but they incorporate both contemporaneous and lagged values of the independent variable, ensuring the exploitation of temporal variation where possible. To control unobserved, time-invariant heterogeneity across establishments, we implement fixed effects models with time, industry and firm fixed effects. As discussed earlier, our final analytic sample includes approximately 28,691 establishments and 90,801 observations, depending on model specification, covering the years 1998 to 2021.

3.2.1 Specification 1 – Baseline

To test Hypothesis 1, we estimate panel data models where the dependent variable is a binary indicator of decentralization (D_{it}), equal to 1 if a firm experienced a downward shift in

[5] The firm age is the age of the firm relative to 2021 (end of the panel). In addition, consistent with prior literature we control for the skill-intensity of the workplace(Caroli & Van Reenen, 2001) by defining a variable that accounts for the percentage of the number of employees that are either unskilled or perform simple tasks. Finally, we also control for the organizational form, while prior literature has found that multinationals have a different organizational form (Bloom, Sadun, & Reenen, 2012), we control this through a binary construct of organizational complexity. Namely, whether the organization is simple (as an individual company or partnership) or not (by other complex forms including corporations, foundations etc.).

decision-making authority in year t, and 0 otherwise. The regression specification is as follows:

$$\mathbf{D_{it}} = \boldsymbol{\alpha} + \sum_{k=0}^{3} \boldsymbol{\beta}_k(\mathbf{ICT_{it-k}}) + \boldsymbol{\gamma}(\mathbf{Z_{it}}) + \boldsymbol{\rho_i} + \boldsymbol{\varphi}_{\mathbf{j}} + \boldsymbol{\tau_t} + \boldsymbol{\varepsilon_{it}}$$

Where:

- (ICT_{it-k}) are binary indicators for whether firm i invested in ICT in year $t-k$,
- (Z_{it}) includes time-varying controls such as standardized log firm size,
- ρ_i, φ_j and τ_t are firm, industry, and year fixed effects, respectively,
- ε_{it} is the random error term.

In addition to the distributed lag specification, we estimate alternative models using cumulative ICT investment indicators across multiple lags (e.g., from t to t−2, or from t−to t−3). All models are estimated using ordinary least squares (OLS) linear fixed effects regression, with standard errors that are heteroskedasticity- and autocorrelation-consistent (HAC) and clustered at the firm level. Hypothesis 1 predicts $\beta_k > 0$, indicating that ICT investments increase the likelihood of decentralization.

3.2.2 Specification 2 – Mega-firms

To test Hypothesis 2, we estimate models that allow the effect of ICT investment on decentralization to vary with firm size. Specifically, we estimate two fixed effects specifications that include interaction terms between lagged ICT investment and alternative measures of firm size.

Model (1): Interaction with (standardized) Firm Size

We first interact ICT investment indicators with a continuous measure of firm size, defined as the standardized natural logarithm of the number of employees:

$$\mathbf{D_{it}} = \boldsymbol{\alpha} + \sum_{k=1}^{3} \boldsymbol{\beta}_k(\mathbf{ICT_{it-k}}) + \boldsymbol{\gamma}(z\mathbf{firm_size_{it}}) + \sum_{k=1}^{3} \boldsymbol{\partial}_k(z\mathbf{firm_size_{it}} \times \mathbf{ICT_{it-k}}) + \boldsymbol{\rho_i} + \boldsymbol{\varphi}_j + \boldsymbol{\tau_t} + \boldsymbol{\varepsilon_{it}}$$

Where:

- (D_{it}) is a binary indicator equal to 1 if firm i experienced a downward shift in decision-making authority in year t, and 0 otherwise.
- (ICT_{it-k}) indicates whether the firm invested in ICT in year $t-k$
- $(zfirm_size_{it})$ is the standardized natural logarithm of firm size (employee count).
- ρ_i, φ_j and τ_t denote firm, industry, and year fixed effects.
- ε_{it} is the random error term.

Model (2): Interaction with Megafirm Status:

Next, we test heterogeneity by structural firm size using a binary indicator for megafirms, defined as firms in the top 5% of the pooled firm size distribution (based on the log of employees across the entire panel, not within-year). This provides a stable classification that is appropriate for fixed effects estimation. The specification is:

$$\mathbf{D_{it}} = \boldsymbol{\alpha} + \sum_{k=1}^{3} \boldsymbol{\beta}_k(\mathbf{ICT_{it-k}}) + \boldsymbol{\gamma}(z\mathbf{firm_size_{it}}) + \sum_{k=1}^{3} \boldsymbol{\partial}_k(\mathbf{mega_firm_i} \times \mathbf{ICT_{it-k}}) + \boldsymbol{\rho_i} + \boldsymbol{\varphi}_j + \boldsymbol{\tau_t} + \boldsymbol{\varepsilon_{it}}$$

Where:

- $(mega_firm_i)$ is a binary indicator equal to 1 if firm i is in the top 5% of the size distribution across the full panel[6]

All models are estimated using ordinary least squares (OLS) linear fixed effects regression, with standard errors that are heteroskedasticity- and autocorrelation-consistent (HAC) and clustered at the firm level. Hypothesis 2 predicts $\partial_k > 0$ for both models, suggesting that the decentralizing effect of ICT investment is stronger in larger firms, particularly among megafirms.

3.2.3 Specification 3 – Time-Varying ICT Effects

To test Hypothesis 3—whether the decentralizing effect of ICT investment has changed over time—we estimate a panel fixed effects model with interactions between ICT investment and a continuous year variable. The model is:

$$\mathbf{D_{it}} = \boldsymbol{\alpha} + \sum_{\boldsymbol{k=1}}^{\mathbf{3}} \boldsymbol{\beta_k}(\mathbf{ICT_{it-k}}) + \boldsymbol{\gamma}(\mathbf{zfirm_size_{it}}) + \boldsymbol{\vartheta}(\mathrm{z}\mathbf{Year}_t) + \sum_{\boldsymbol{k=1}}^{\mathbf{3}} \boldsymbol{\delta_k}(z\mathbf{Year_t} \times \mathbf{ICT_{it-k}}) + \boldsymbol{\rho_i} + \boldsymbol{\varphi_j} + \boldsymbol{\varepsilon_{it}}$$

Where:

[6] The megafirm indicator is defined based on the top 5% of the pooled firm size distribution across all years. This time-invariant classification ensures that megafirm status captures persistent size-based organizational characteristics (e.g. multinational status) rather than temporary year-to-year fluctuations.

- (D_{it}) is a binary indicator equal to 1 if firm i experienced a downward shift in decision-making authority in year t, and 0 otherwise.
- (ICT_{it-k}) indicates whether the firm invested in ICT in year $t-k$
- $(zfirm_size_{it})$ is the standardized natural logarithm of firm size (employee count).
- $(zYear_t)$ is the standardized continuous year variable (1993-2021).
- ρ_i, φ_j and τ_t denote firm, industry, and year fixed effects.
- ε_{it} is the random error term.

This model captures whether the effect of ICT investment on decentralization has intensified or diminished over time. All models are estimated using ordinary least squares (OLS) with firm fixed effects, and standard errors are heteroskedasticity- and autocorrelation-consistent (HAC), clustered at the firm level. Hypothesis 3 predicts $\delta_k < 0$, indicating that the decentralizing impact of ICT investment weakens over time.

4. Results

4.1 Baseline Results

Table 2 presents estimates from six regression models examining the relationship between ICT investment and the decentralization of decision-making authority. The models vary along three key dimensions: (i) the timing of ICT investment (contemporaneous vs. lagged), (ii) the structure of the ICT variable (binary, cumulative, or categorical), and (iii) the inclusion of firm fixed effects to control for time-invariant firm heterogeneity. All models include year and industry fixed effects and control for the firm size. Columns (1) to (3) rely on single-year ICT investment indicators, while Columns (4) to (6) incorporate multi-year measures to capture the potential for sustained or compounding organizational effects of ICT investments.

Across all models, ICT investment(s) are positively and statistically significantly associated with decentralization at the 1% level, though coefficient magnitudes vary by specification.

A key finding emerges from comparing Columns (2) and (3), which are identical except for the ICT timing. ICT investment in the previous business year (Column 3) leads to a 3.7 percentage point increase in the likelihood of decentralization, compared to only 1.4 percentage points ICT investment in the same year (Column 2). This suggests that decentralization responds with a delay to ICT implementation, consistent with the time needed for organizational routines and technologies to take effect.

Models using contemporaneous ICT measures (Columns 1, 2, and 4) in Table 2 are susceptible to simultaneity bias, as decentralization decisions may themselves influence current-year ICT investments. To mitigate this concern, in Columns (3), (5), and (6) ICT investment precedes observed decentralization outcomes.

Columns (4)–(6) in Table 2 incorporate multi-year measures to capture the cumulative effects of ICT. Column (5) uses a three-year lagged cumulative index, while Column (6) includes separate binary indicators for ICT adoption in each of the past three years (t–1, t–2, t–3). Column (6) is our preferred model specification for three reasons: (i) it uses only lagged ICT measures, reducing the risk of reverse causality; (ii) it allows for heterogeneous, non-linear effects over time; and (iii) it yields the highest model fit and within R^2 among all fixed effects models.

In our preferred model specification (Column 6) in Table 2, ICT investments in the previous business year (t–1) are associated with a 3.6 percentage point increase in the likelihood of decentralization, while ICT investments two and three years prior (t–2 and t–3) correspond to increases of 1.1 and 0.7 percentage points in the likelihood of decentralization, respectively.

These coefficients are all statistically significant at the 1% level and reflect the marginal effects of ICT adoption in that specific year, controlling for adoption in other years. These effects are additive: a firm that invested in ICT in all three previous business years has a 5.4 percentage point higher probability of decentralization than a firm that invested in none of those years.

Taken together, these results support **Hypothesis 1**, which posits investments in ICT lead to a sustained increase in the decentralization of decision-making authority within organizations over time.

4.2 Firm size as a moderator

Table 3 presents the results for Hypothesis 2, using two complementary specifications to examine whether the decentralizing effects of ICT investment vary by firm size. Both Model (1) and (2) extend the preferred specification from Table 3 by including ICT investments in the previous business year, two years prior, and three years prior.

Model (1), reported in Column (1) of Table 3, interacts ICT investments with a continuous measure of standardized firm size (log of employees). The interaction between firm size and ICT investment in the previous business year is positive and statistically significant at the 10% level, suggesting some support for the hypothesis that larger firms experience a stronger short-run decentralizing effect from ICT. Specifically, a one standard deviation increase in firm size amplifies the decentralizing effect of ICT investment in the prior year by **0**.69 percentage points. However, this effect does not persist over time: the interaction terms for ICT investment two years prior (a decline of 0.45 percentage points) and three years prior (an increase of 0.37 percentage points) are not statistically significant and show inconsistent signs, indicating that the firm size-based amplification effect of ICT investments on decentralization may be short-lived.

Model (2) considers mega-firm status by interacting ICT investment with a "megafirm" indicator for firms in the top 5% of the firm size distribution. None of the interaction terms are statistically significant: in terms of magnitude however, the effects on decentralization are 2.37 percentage points higher for ICT investment in the previous business year, 0.31 percentage points higher for two years prior, and 0.60 percentage points lower for three years prior for megafirms compared to non-megafirms. This pattern mirrors the results in Model (1), suggesting somewhat limited and unstained evidence that mega-firms systematically experience stronger decentralization effects from ICT.

Further insight comes from marginal effects analysis in Figure 2. Among non-megafirms, ICT investment in the previous business year increases the likelihood of decentralization by 3.65 percentage points (significant at the 1% level), while the effect for megafirms is 5.97 percentage points (significant at the 10% level, with wide confidence intervals). For ICT investment two years prior, the effect is 1.17 percentage points for non-megafirms (statistically significant), but only 1.37 percentage points for megafirms (not significant). For investment three years prior, the effect remains 0.87 percentage points for non-megafirms (statistically significant) but drops to just 0.22 percentage points for megafirms (not significant).

Taken together, these findings do not provide support Hypothesis 2, which posited that ICT would have stronger decentralizing effects in larger firms. While there is some evidence that large firms—particularly megafirms—may exhibit a short-term stronger decentralizing response to ICT investment in the immediate year following investment, these effects wane quickly and are not statistically robust over time. The lack of sustained significance in interaction terms, especially for megafirms, suggests that larger firms tend to retain centralized managerial control, even after investing in new digital technologies. This may reflect greater

organizational inertia, hierarchical rigidity, or perhaps a deliberate choice to use ICT to enhance oversight rather than devolve authority.

In contrast, small and mid-sized firms demonstrate more consistent and persistent decentralization in response to ICT investment, possibly due to greater organizational agility, flatter structures, or lower costs of implementing structural change. While firm size may influence the initial timing of decentralization, the broader pattern contradicts the view that ICT investments lead to stronger or more durable decentralization in large firms.

4.3 Time-varying ICT effects

Column (3) of Table 3 presents the results for Hypothesis 3, which posits that the effect of ICT investment on decentralization has weakened over time. All models build on the preferred lagged ICT specification from Table 1, including ICT investments in the previous business year, as well as two and three years prior (t–1 to t–3).

Column (3) of Table 3 introduces interactions between ICT investment in previous business years and a continuous year variable (standardized). These interactions allow us to assess whether the marginal effect of ICT has increased or diminished over time. Across all three previous business year(s) the ICT × Year interaction terms are negative and statistically significantly associated with decentralization at the 1% level, indicating that the decentralizing effect of ICT investments has declined in more recent years compared to earlier years and providing strong support for Hypothesis 3.

Specifically, for ICT investments made in the previous business year, the marginal effect on decentralization has weakened over time by 1.2 percentage points. Similarly, ICT investments made two years prior, and three years prior have reduced the effect by 1.0 and 0.3 percentage points, respectively.

Or in other words, if a firm invested in ICT in all three previous business years, the total decentralizing effect of those investments would on average be 2.5 percentage points weaker in later years (e.g., the 2010s) compared to earlier years in the panel (e.g., the 1990s), due to the cumulative negative interaction with time.

These findings imply that ICT investments in earlier years of the panel (e.g., the 1990s and early 2000s) had stronger decentralizing effects, whereas more recent ICT investments (post-2010) have more centralizing effects. This trend could reflect diminishing returns to ICT investments, organizational saturation, or that recent digital technologies enhance oversight rather than devolving authority.

Taken together, these findings are consistent with Hypothesis 3: The effect of ICT investments on decentralization of decision-making authority has **weakened** over time.

5. Discussion

5.1. Findings and Implications

Our findings offer a nuanced perspective on the evolving relationship between digital technologies and organizational structure, contributing to a growing literature that reexamines the decentralizing potential of ICT (Acemoglu et al., 2007b; Bloom et al., 2014b; Bresnahan et al., 2002; McElheran, 2014).Using rich establishment level panel and lagged ICT measures to mitigate simultaneity concerns, we find robust evidence that ICT investment is associated with greater decentralization of decision-making authority, particularly in the years following implementation. This supports longstanding theories that digital technologies reduce information asymmetries and coordination costs, thereby enabling the delegation of authority to lower organizational levels ((McElheran, 2014). However, the attenuation of this relationship when establishment fixed effects are introduced suggests that earlier studies may have

overstated the causal impact of ICT on decentralization. Much of the variation appears to be driven by stable, between-firm differences rather than within-firm organizational change.

Crucially, our results also reveal key temporal and contextual limitations to the decentralizing effect of ICT. First, consistent with Hypothesis 3, we find that the magnitude of ICT's decentralizing impact has declined over time. Interaction terms between ICT and year indicate a statistically significant weakening of this effect, suggesting that more recent ICT investments—particularly those made later—are less likely to facilitate downward shifts in authority. This may reflect diminishing marginal returns, the maturity of digital technologies, or a shift in how firms deploy these systems—from early applications that enabled autonomy to newer tools, such as artificial intelligence, that enhance oversight and centralized control.

Second, we find that firm size moderates the relationship between ICT and decentralization, but not in a consistent or statistically robust manner. While larger firms tend to be more decentralized on average, the interaction terms between ICT investment and both firm size and megafirm status are generally not significant in our multi-year lagged specifications. This challenges the notion that digital technologies inherently amplify decentralization in large, complex organizations(Acemoglu et al., 2007a; Garicano, 2000)

Our findings support recent critiques that emphasize managerial discretion and heterogeneity in how digital technologies are used across firms (Autor et al., 2022; Bloom, Sadun, & Reenen, 2012). In particular, they suggest that contemporary digital tools—especially AI and predictive analytics—may be less about empowering lower-level autonomy and more about reinforcing centralized coordination, surveillance, and performance monitoring (Zuboff, 2019).

Finally, we find that early ICT adopters in the 2000s experienced stronger decentralization effects than more recent adopters, pointing to a shift in the functional role of technology within firms. In earlier periods, ICT may have facilitated structural change and organizational learning; more recently, it may be used to consolidate decision rights and reinforce centralized hierarchies, especially as firms scale their data collection and integration capabilities.

5.2. Limitations and Future Research

Our study has several limitations that open avenues for future research. First, our ICT measures are necessarily coarse and do not differentiate among specific technologies such as enterprise resource planning(ERP) systems, cloud infrastructure, or AI-enabled tools. As prior work highlights (Bloom et al., 2014; Brynjolfsson & McElheran, 2016), the organizational consequences of digital technologies are highly heterogeneous, shaped both by the functional characteristics of the technology and the context in which it is deployed. Disentangling the effects of specific ICT types—and the complementary organizational practices they require—remains a key direction for future research, one that will likely depend on richer, more granular and recent data collection.

Second, although we mitigate simultaneity and firm-specific time-invariant endogeneity concerns using lagged ICT measures and firm fixed effects, unobserved shocks that jointly influence both ICT investment and decentralization cannot be entirely ruled out. Stronger identification strategies—such regulatory discontinuities or instrumental variables—would help validate the mechanisms at play.

Third, while we document structural changes in internal authority allocation, we do not observe downstream implications for worker outcomes or firm performance. The impact of

ICT-induced decentralization on productivity, employee autonomy, and organizational inequality remains salient as firms increasingly adopt frontier technologies with possibilities of algorithmic management, remote monitoring, and platform-based coordination tools that may reshape how control is exercised and distributed within firms.

Lastly, our findings speak to an underdeveloped dimension of the literature on skill-biased technological change (SBTC). While SBTC emphasizes the labor market effects of technology via the polarization of occupations and tasks (Autor et al., 2024; Michaels et al., 2014), its implications for *intra*-organizational hierarchies are less well understood. Emerging evidence (Autor et al., 2024) suggests technology-induced shifts in task composition—particularly the displacement of routine managerial oversight—may alter not only who performs work, but who holds decision-making authority. Future research should investigate how evolving task boundaries mediate authority structures inside firms, and whether technological change flattens or reinforces managerial hierarchies in practice.

6. Conclusion and Policy Implications

This study provides novel evidence on the evolving relationship between information and communication technologies (ICT) and the decentralization of decision-making within firms. Using establishment-level panel data from Germany spanning 1998 to 2021, we find that ICT investments are associated with a sustained increase in decentralization, particularly in the years following adoption. However, these effects are not uniform: the strength of the ICT–decentralization relationship has weakened over time, varies inconsistently with firm size, and appears sensitive to broader organizational and technological context.

Contrary to expectations that larger firms would exhibit stronger decentralization in response to digital tools, we find only short-lived or statistically insignificant interaction effects.

Instead, smaller firms appear more consistently responsive to the decentralizing potential of ICT. Moreover, our results suggest that more recent technologies—especially post-2010—may facilitate centralized oversight rather than downward delegation, reflecting a shift in the functional role of digital systems from enabling autonomy to enforcing control.

From a policy perspective, these findings underscore the importance of supporting not only technological diffusion but also organizational models that preserve worker autonomy. As digital infrastructures mature, there is a growing risk of recentralization unless decentralization is actively maintained through complementary investments in human capital, participatory governance, and adaptive management practices. While decentralization is often linked to greater employee empowerment, innovation, and job satisfaction (Bartling et al., 2014), our evidence points to its uneven and potentially declining distribution across firms and over time.

This raises important questions for future research and policy: How do changes in internal authority structures affect labor market outcomes? What role should public institutions play in shaping the organizational consequences of digital transformation?

Ultimately, our findings suggest that the relationship between technology and organizational hierarchy is contingent, dynamic, and policy relevant. To ensure that digital transformation supports inclusive and innovative economic outcomes, institutional actors must attend not only to *what* technologies firms adopt, but also to *how* those technologies are integrated into decision-making and workplace governance. Furthermore, as megafirms continue to expand in scope and scale, there is also a growing need to monitor not just market concentration, but the internal distribution of authority and decision rights within these dominant firms.

Table 2: ICT Investments on (De)centralization: Downward-shifting responsibilities/(Worker) Autonomy

Dependent = Decentralization (Downward Responsibility)	Model (1)	(2)	(3)	(4)	(5)	(6)
ICT investment *(t)* (0/1)	0.042*** (0.002)	0.014*** (0.004)	-	-	-	-
ICT investment *(t-1)* (0/1)	-	-	0.037*** (0.003)	-	-	0.036*** (0.003)
ICT investment *(t-2)* (0/1)	-	-		-	-	0.011*** (0.003)
ICT investment *(t-3)* (0/1)	-	-		-	-	0.008*** (0.003)
Cumulative ICT investments *(t to t-2)*	-	-		0.019*** (0.002)	-	-
Cumulative ICT investments *(t-1 to t-3)*	-	-		-	0.018*** (0.002)	-
Firm Size (standardized)	0.056*** (0.002)	0.028*** (0.009)	0.031*** (0.008)	0.022** (0.009)	0.027*** (0.008)	0.028*** (0.008)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Establishment fixed effects	No	Yes	Yes	Yes	Yes	Yes
Overall R2	0.065	0.034	0.045	0.044	0.046	0.047
Within R2	0.010	0.013	0.015	0.015	0.015	0.016
Between R2	0.105	0.050	0.067	0.065	0.070	0.072
No. of observations	72,217	72,217	90,801	72,217	90,801	90,801
No. of establishments	23,204	23,204	28,691	23,204	28,691	28,691

Notes: The dependent variable is a binary indicator equal to 1 if decision-making responsibilities shifted downward within the organizational hierarchy (i.e., decentralization), and 0 otherwise. All models are estimated using a Linear Probability Model (LPM). The main independent variable, ICT investment (t-1), equals 1 if the establishment reports operational investments in Electronic Data Processing (EDP) or Information and Communication Technologies (ICTs) in the previous business year, and 0 otherwise. Several models include lagged or cumulative ICT investment indicators (e.g., *t–1*, *t–2*, *t–3*) to capture delayed or persistent organizational effects. Firm size is measured as the standardized natural logarithm of the number of employees in June of each business year (mean = 0, SD = 1). Industry fixed effects are based on harmonized 2-digit industry classifications, adjusted for coding revisions in 2000 and 2009. All models include year and industry fixed effects, while Columns (2)–(6) additionally include establishment fixed effects to account for time-invariant heterogeneity.. Heteroskedasticity- and autocorrelation-consistent (HAC) standard errors clustered at the firm level are reported in parentheses. The number of observations and unique establishments is reported at the bottom of the table. Significance levels: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

Table 3: ICT Investments on (De)centralization: Moderating Role of Firm Size & Time-varying ICT Effects

Dependent = Decentralization (Downward Responsibility)	Model (1)	(2)	(3)
ICT Investment(s)			
ICT investment *(t-1)* (0/1)	0.037*** (0.003)	0.036*** (0.003)	0.042*** (0.003)
ICT investment *(t-2)* (0/1)	0.011*** (0.003)	0.011*** (0.003)	0.015*** (0.003)
ICT investment *(t-3)* (0/1)	0.008** (0.003)	0.008** (0.003)	0.009** (0.003)
Interactions: ICT × Firm Size			
ICT investment *(t-1)*×Firm Size (Standardized)	0.007* (0.004)	-	-
ICT investment *(t-2)*×Firm Size (Standardized)	-0.004 (0.004)	-	-
ICT investment *(t-3)*×Firm Size (Standardized)	0.004 (0.004)	-	-
Interactions: ICT × Megafirm			
ICT investment *(t-1)*×Megafirm	-	0.024 (0.027)	-
ICT investment *(t-2)*× Megafirm	-	0.003 (0.026)	-
ICT investment *(t-3)*× Megafirm	-	-0.006 (0.028)	-
Interactions: ICT × Year			
ICT investment *(t-1)*×Year (Standardized)	-	-	-0.012*** (0.003)
ICT investment *(t-2)*× Year (Standardized)	-	-	-0.010*** (0.003)
ICT investment *(t-3)*× Year (Standardized)	-	-	-0.003 (0.003)
Firm Size (standardized)	0.026*** (0.008)	0.028*** (0.008)	0.033*** (0.008)
Megafirm (0/1)	-	-0.022 (0.042)	
Year (standardized)	-	-	-0.001 (0.003)
Year fixed effects	Yes	Yes	No
Industry fixed effects	Yes	Yes	Yes
Establishment fixed effects	No	Yes	Yes
Overall R2	0.048	0.047	0.050
Within R2	0.016	0.016	0.014
Between R2	0.072	0.071	0.078
No. of observations	90,801	90,801	90,801
No. of establishments	28,691	28,691	28,691

Notes: The dependent variable is a binary indicator equal to 1 if decision-making responsibilities shifted downward within the organizational hierarchy (i.e., decentralization), and 0 otherwise. All models are estimated using a Linear Probability Model (LPM). The main independent variable(s), ICT investment (t-k), equals 1 if the establishment reports operational investments in Electronic Data Processing (EDP) or Information and Communication Technologies (ICTs) in the business year t-k, and 0 otherwise, where k={1,2,3}. Firm size is measured as the standardized natural logarithm of the number of employees in June of each business year (mean = 0, SD = 1). The years of the panel are from 1998 to 2021. Megafirm is a binary indicator equal to 1 if the firm size distribution is in top 5% of the pooled panel of firms from 1998-2021, and 0 otherwise. Industry fixed effects are based on harmonized 2-digit industry classifications, adjusted for coding revisions in 2000 and 2009. All models include year and industry fixed effects, and establishment fixed effects. Heteroskedasticity- and autocorrelation-consistent (HAC) standard errors clustered at the firm level are reported in parentheses. The number of observations and unique establishments is reported at the bottom of the table. Significance levels: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

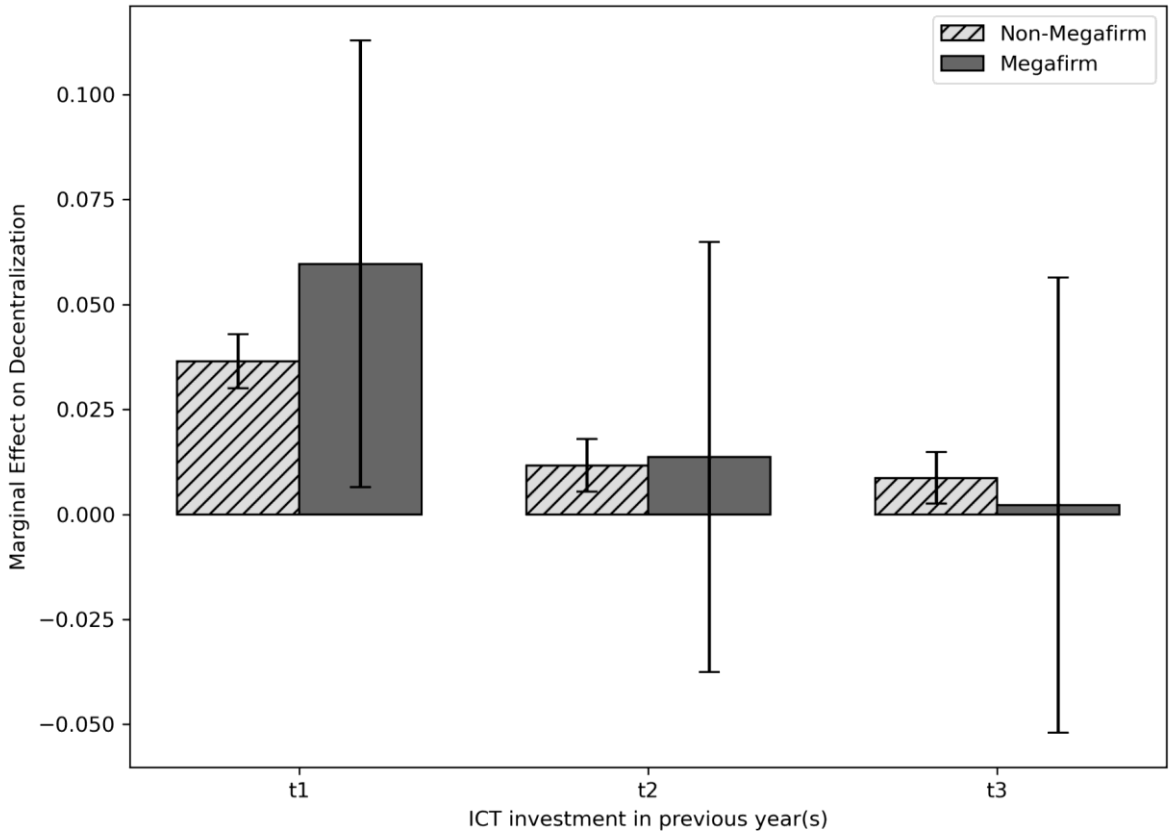


Figure 2: Marginal Effects of ICT on Decentralization for (non)-Megafirms

Notes: This stacked bar chart displays the average marginal effects of ICT investments in previous business year(s) 1,2 and 3 on the probability of decentralization. The x-axis represents the timing of ICT investments in previous years, while the y-axis shows the average estimated marginal effect on decentralization (ranging from –0.05 to 0.10). Bars distinguish between non-Megafirms (hatched) and Megafirm (solid gray) establishments. Vertical lines indicate 95% confidence intervals, reflecting statistical uncertainty around each estimate. Marginal effects are derived from a fixed effects linear probability model with clustered standard errors, and regression specification of Column 2 of Table 2.

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