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Does digitalization of government activities improve business environment? The influence of public service standardization☆

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ABSTRACT

This study examines how digitalization of government activities improves the business environment. Unlike previous studies that have emphasized transparency, our research examines the role of government's information and communication technology adoption in establishing standardized procedures for public service provision. Initially, offline services imposed higher costs due to individual discretion. However, the emergence of online platforms introduced clear standards, which prompted offline channels to align with these norms. Consequently, firms are able to access public services at reduced costs, whether online or offline, compared with the pre-digitalization period. We test the predictions of our general equilibrium model using cross-country data from 2003 to 2019. Results from instrumental variable estimations demonstrate that the enhanced scope and quality of online government services have causally improved the business environment, predominantly by reducing firms' compliance costs, confirming our theoretical model's predictions. These findings highlight the importance of standardized service delivery for optimizing public service effectiveness.

1. Introduction

A consistent business environment is crucial for business operations and economic growth (He et al., 2025), and an unsatisfactory business environment can impede firms from obtaining necessary public services, which is particularly common in developing countries (Martins and Veiga, 2022; Mogues et al., 2023). One potential way to improve the business environment is to integrate information and communication technology (ICT) into governance. Such digitalization could enhance social welfare, primarily by reducing information asymmetry (Okunogbe and Pouliquen, 2022; Gan et al., 2023; Ding et al., 2024), enhancing administrative transparency (Bellon et al., 2022; Das et al., 2023), and standardizing processes. Nevertheless, previous research has focused on individual digital channels, with limited investigations regarding potential spillover effects.

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This study focuses on the uniformity of common service standards established by digital platforms across online and offline channels, which is a critical yet frequently overlooked aspect of government activity digitalization. As the digitalization of government activities evolves, online platforms and offline channels must provide homogeneous public services to ensure consistent application processes and identical documentation requirements (United Nations, 2012). We contend that the requirement of uniformity is crucial for improving the overall business environment, even when digital technology is predominantly applied in the online platform.

In the era that did not include government activity digitalization, public service processing was exclusively conducted offline. Variations in the time and cost associated with manual document handling by staff posed challenges for the government to establish a common standard across public services. The lack of clear standards resulted in prolonged processing procedures and waiting times for the government to manage and scrutinize firms' documents, inflating the operational costs borne by firms.[1]

The introduction of online platforms causes a notable transformation. By reducing inconsistencies in manual processes conducted by staff, computerized applications standardize processing times and workflows, enabling the government to set clear standards when providing public services.[2] Therefore, the streamlined framework reduces costs for delivering public services via the online platform. The government then sets lower prices due to reduced costs. To maintain uniformity in service delivery across channels, firms can also access public services at a reduced uniform price through offline channels. The reduced price stimulates higher demand for public services from firms, reinforcing the business environment.

We construct a general equilibrium model to investigate the above rationale, defining the business environment as the quantity of public services that firms must acquire to engage in production. In our model, the absence of online platforms results in public services that are exclusively accessible through offline channels, leading to a public service market with high prices and profits. When potential users reach a threshold, the government introduces an online platform. Even if only a portion of firms use online platforms, the average (or expected marginal) cost of public service provision decreases. Considering that the government establishes optimal public service prices as a constant markup above marginal costs, the lower marginal cost associated with the online platforms reduces the optimal public service prices, which boosts the quantity of public services and improves the business environment. We call this phenomenon the compliance cost effect. Although the government also increases tax rates to finance government activity digitalization, which indirectly lowers the demand for public services, the compliance cost effect dominates consistently. Consequently, our model demonstrates that the digitalization of government activities can improve the equilibrium business environment.

We test the prediction of our theoretical model with data covering 167 countries from 2003 to 2019 with a focus on assessing how government activity digitalization shapes the business environment. However, fixed effect (FE) estimations may produce biased estimates due to the inherent endogeneity in the digitalization of government activities. For example, a country's economic development could jointly determine the adoption of digital tools in public administration and shifts in business environment quality, introducing omitted variable bias. Moreover, endogeneity in government activity digitalization is also an inherent feature of our theoretical framework. To alleviate this concern and demonstrate the causality between government activity digitalization and the business environment, we use post-World War II birth rates (i.e.,1950–1955) to construct instrumental variables (IVs) for the digitalization of government activities. Specifically, our empirical strategy tracks the age progression of individuals born between 1950 and 1955 over the period from 2003 to 2019 to examine the impact of aging on the demand for digitalized government activities.

ICT advancements are the driving force of business environment improvement in our study, which we demonstrate to be a significant contributor to public service delivery. Some studies have shown that the widespread use of ICT in governance allows policymakers to have better access to big data and artificial intelligence technology to improve decision-making (Elbahnasawy, 2021; Haseeb and Vyborny, 2022; Mehmood et al., 2023; Filiou et al., 2023). Mastrobuoni (2020) demonstrated that the police productivity in Milan increased when policemen can access information about previous incidents to predict criminals' strategy. Other studies have found that ICT increases the transparency of public programs and improves political accountability (Lewis-Faupel et al., 2016; Muralidharan et al., 2016; Fan et al., 2020; Okunogbe and Pouliquen, 2022; Dzansi et al., 2022; Das et al., 2023). Banerjee et al. (2020) provided empirical evidence that the adoption of e-invoicing in India reduced the leakage of public funds, suggesting that this is because misreporting is now easier to detect. Okunogbe and Tourek (2024) demonstrated that ICT aids tax collection by reducing information asymmetry between the government and taxpayers and between tax officials and higher-level government authorities. The literature on ICT's influence on reducing the costs of entrepreneurial activities also informs our study. For example, Goldfarb and Tucker (2019) determined that ICT has changed many aspects of operation costs, including hiring workers (Forman et al., 2012; Autor et al., 2015; Acemoglu et al., 2022), targeting potential consumers (Athey et al., 2018; Prat and Valletti, 2022), advertising (Lee and Hosanagar, 2021), and interfirm communication (Bloom et al., 2014).

Our study also relates to the research regarding different aspects of the business environment. Previous studies have demonstrated that firms' inability to access low-cost public services can diminish total factor productivity and an economy's total output (Divanbeigi and Ramalho, 2015). A significant body of research has examined the influence of governmental provision of market entry procedures for new entrants. For example, Herrendorf and Teixeira (2011) constructed a general equilibrium model, revealing that high barriers to firm entry in developing countries could be correlated with half of the income gap with the United

[1] For example, building permit processing durations in California differ by project scale and administrative delays, ranging from weeks for minor repairs to months for new installations. See https://symbium.com/blog/why-do-permit-applications-take-so-long-to-get-approved.

[2] Marienfeldt (2024) demonstrates that government activity digitalization reduces discretionary power among personnel, especially for low-complexity, routine tasks, by enforcing clear standards aligned with regulations.

States (US). Government regulations pertaining to firm entry were also found to affect the number and size of firms entering the market (Klapper et al., 2006), firms' technology choices (Poschke, 2010), exports (LiPuma et al., 2013), and employment (Branstetter et al., 2014). Other strands of research have addressed the effects of digitalization on various aspects of the business environment such as the impact of tax filing convenience on corporate tax compliance (Kochanova et al., 2020), the influence of easier electricity connectivity on the operations of firms in electricity-intensive industries (Geginat and Ramalho, 2018), and the impact of improved property rights protection on firm value (Berkowitz et al., 2015).

This study contributes to the existing literature in several ways. We contribute to ICT-related literature by exploring the requirement of consistent processes across online and offline services, which has been a less examined mechanism through which ICT can enhance the business environment. As the marginal cost of delivering online government services is relatively low, governments are able to develop standardized, cross-platform procedures for service provision by considering the marginal costs associated with online and offline approaches. This procedure, which is intended to optimize government departments' own utility, is more efficient than the processes before the emergence of digital platforms. Furthermore, our approach diverges from conducting randomized controlled trials on specific public services in a single developing country as we use cross-country data, which enables us to assess the broader impact of ICT on international governance.

Our work also extends the literature on ICT's influence on reducing entrepreneurial costs by investigating how ICT affects firms' costs to obtain public services. While the majority of existing studies have focused on costs generated by firm decisions, we explore how ICT influences the costs imposed by the government, such as payments for public services. Our findings provide a more comprehensive understanding of the ways in which ICT reduces barriers to entrepreneurial activities.

Additionally, this study contributes to business environment literature by examining how digitalization of government activities can enhance the business environment through the consistent supply of public services. We propose that harmonizing online and offline service standards reduces firms' expenses to access these services, fostering an improved business environment. Our perspective diverges from existing research that has primarily focused on the effects of the business environment on economic growth, offering a novel perspective concerning how digital transformation can enhance government efficiency.

The remainder of this paper is organized as follows. Section 2 provides background information regarding government activity digitalization from a global perspective. Section 3 presents our general equilibrium model and demonstrates how government activity digitalization could affect the business environment. Section 4 introduces the study's data and empirical strategy. Section 5 details the benchmark results, and Section 6 examines the mechanisms and additional results. Finally, Section 7 concludes by summarizing the findings and providing several policy implications.

2. Background: Government activity digitalization development

With rapid ICT development, governments across the globe have been diligently crafting and implementing government activity digitalization, employing a variety of policies and digital strategies to meet citizens' needs. While the specifics may vary across countries, the global evolution of government activity digitalization exhibits several shared features.

By definition, government activity digitalization uses ICT (particularly the internet) to transform government services and operations into digital forms. The primary goals of digitalization are to enhance service delivery efficiency, increase transparency, and improve public access by providing online platforms for applications, payments, and the dissemination of information (Halachmi and Greiling, 2013; Bhuasiri et al., 2016). This digital shift fosters greater citizen engagement and optimizes government workflows. In practice, an expanding array of public services has now become accessible through online portals, with a growing number of countries enabling the public to obtain specific services via online platforms. For example, according to *E-Government Surveys*, online business registration services have expanded, and the number of countries offering this capability has increased from 60 in 2013 to 97 in 2015, reaching 162 by 2019. However, the extent of government activity digitalization differs across nations. While some have succeeded in providing comprehensive online services, others have yet to catch up, implying that the costs for public access to services differ. Residents face lower costs in countries with more online services because online access offers greater convenience. The countries with the highest levels of government activity digitalization are predominantly located in North America, Europe, East Asia, and Oceania. Conversely, regions such as Africa, the Middle East, and Southeast Asia exhibit relatively lower government activity digitalization.

Intuitively, the introduction of government activity digitalization has a positive impact on the business environment (Martins and Veiga, 2022). The main reason is that government activity digitalization establishes a clear government benchmark for the time and procedures involved in public service provision. Prior to the integration of digital systems, government officials have a considerable degree of discretionary power (Johnson et al., 1998). Developing a precise benchmark can be challenging due to the variations in time and costs associated with different staff members' manual document processing. Nevertheless, the lack of individual idiosyncrasies in computerized document processing reduces such discretion, enabling the government to establish common standards that define the time and procedures involved in public service provision (Scholta et al., 2015; Buffat, 2015). These standards are often made explicit by the online platform, detailing each step's waiting time, associated fees, and required documentation.[3]

Platforms' standards ensure that online and offline services are identical, prompting inclusivity for all citizens. The continued need for offline channels is because not everyone has equal access to online services. Some regions may suffer from unstable internet

[3] The website of the United Kingdom government states that effective government services must disclose processing time, associated costs, and decision deadlines. See https://www.gov.uk/service-manual/design/introduction-designing-government-services.

connectivity, or specific demographic groups such as the elderly and less educated might lack the skills required to navigate online platforms. Consequently, offline service outlets must be available, and since they provide the same government services as their online counterparts (e.g., business licenses or construction permits), they must adhere to the same standards. For example, in 2022, the State Council of China issued guidelines to improve the capabilities of offline service provision and ensure that they match the standards set by online services.[4] This policy ensured that online and offline providers administer services based on the same set of uniform criteria.

Standards also lower the price of public services based on the clear procedural benchmarks provided by the online platform. As the online platform incurs lower costs when processing additional government services, the government can establish simpler processes, reducing firms' cost to access these services. For instance, Finland's adoption of online processes not only expedited the business registration procedure but also lowered the fees required. Similarly, India and Saudi Arabia enhanced their international trade capabilities by upgrading port infrastructure and electronic platforms concurrently (World Bank, 2020).

In summary, an increasing number of countries have been using online platforms to deliver a broader spectrum of consistent services at lower cost. The imperative of upholding uniform standards between online and offline services has also improved service delivery quality. The provision of accessible services lowers the costs and increases the quantity of government services. In other words, digitalization has contributed to enhancing the overall business environment.

3. Benchmark model

In this section, we construct a general equilibrium framework to provide a holistic understanding of the intricate interplay between government activity digitalization and the business environment.

Consider a static economy populated by perfectly competitive firms producing a homogeneous final good, which also serves as the numeraire. Referencing the framework for public services in Barro (1990), we assume that the aggregate production function of final goods is a constant return to scale Cobb–Douglas function as follows:

$$Y = \frac{1}{1-\alpha} A^{\alpha} L^{1-\alpha}, \tag{1}$$

where Y represents the final good, L denotes labor, A signifies the quantity of public services, and $\alpha \in (0, 1)$ indicates the output elasticity of public services. The aggregate supply of labor in the economy is denoted as $\overline{L}$.[5]

To operationalize the business environment concept, we define it as the quantity of public services provided to firms (A). From firms' perspective, a higher quantity of public services provided by the government indicates a more favorable business environment. Public services include administrative approvals and government-provided services intended to facilitate firms' production activities. Firms can acquire public services via traditional or digital channels. Although firms can only select one channel for service acquisition, the services obtained from these channels are exact substitutes for one another. Only a single price is incurred for public services (P) regardless of which channel is used to obtain them.

Based on the setup for specialized durable producers in Romer (1990), the government uses the final good as an input for the production of public services, with the production technologies embedded in one of the two channels. The traditional channel can convert m_1 units of final output into one unit of public services, whereas the digital channel can provide services at a marginal cost of m_2, where $m_2 < m_1$, because of the standardization of online public service provision processes. Let $0 < \theta < 1$ denote the adoption rate of the digital channel or the (expected) proportion of local firms that will acquire public services through the digital channel. For analytical simplicity, we assume that θ is exogenously given; therefore, the total cost of delivering public services is $(m_1(1-\theta) + m_2\theta)A$.

The government must determine whether to launch a digital channel with an *ex-ante* investment of $\beta Y \geqslant 0$ before any production activities, where $0 < \beta < 1$ regulates the technological feasibility of constructing the digital channel. If the government does not introduce a digital channel, access to public services is solely limited to the traditional channel. The investment to launch the digital channel increases with Y, indicating that the construction complexity of the digital channel is proportional to the total output. We assume the *ex-ante* investment to be linear to simplify our analysis. We also extend the model to analyze the effects of corruption on government digitalization and business environment efficacy, validating our core conclusions and extending empirical relevance for corruption-prevalent economies.[6]

The government runs a balanced budget. Firms' revenue is taxed at a rate of τ, and the revenue collected through taxation is allocated toward covering the costs associated with public service delivery through the two channels and the installation of the digital channel.

[4] See https://www.gov.cn/zhengce/content/2022-03/01/content_5676259.htm.

[5] We exclude capital from the production function for two reasons. First, capital is excluded to isolate the role of government activity digitalization from dynamic capital accumulation complexities. Second, while capital is essential for digital infrastructure, we instead allocate a portion of final output to cover its construction cost, as capital itself is derived from output in the single-output model conventions.

[6] The details are described in Appendix A. We are grateful to the anonymous referees for highlighting this issue.

3.1. Specification excluding the digital channel

We start by examining a scenario in which the government does not implement a digital channel. Under this circumstance, the government only provides public services through the traditional offline channel. The sequential order of decision-making within the economy unfolds as follows. (1) The government first determines the tax rate (τ) and then the price of public services (P), and (2) firms make decisions regarding final goods production.

In the context of a perfectly competitive final goods market, firms take the costs of labor and public services as given, and the inputs' costs equal the marginal product in equilibrium. Firms' drive for profit maximization implies the following demand function for public services:

$$P = (1-\tau)\frac{\alpha}{1-\alpha}A^{\alpha-1}L^{1-\alpha}. \tag{2}$$

In addition, the market clearing condition of labor immediately implies $L = \overline{L}$. Then, akin to the specialized durable producers in Romer (1990), the government acts as a monopolist within the public service market and maximizes its profit ($PA - m_1 A$), subject to Eq. (2). The first-order conditions imply the following:

$$P = \frac{m_1}{\alpha}, \tag{3}$$

$$A = \left(\frac{\alpha}{m_1}\frac{\alpha}{1-\alpha}(1-\tau)\right)^{\frac{1}{1-\alpha}}\overline{L}. \tag{4}$$

Substituting Eq. (4) into the production function yields the following gross economic output:

$$Y = \frac{1}{1-\alpha}\left(\frac{\alpha}{m_1}\frac{\alpha}{1-\alpha}(1-\tau)\right)^{\frac{\alpha}{1-\alpha}}\overline{L}, \tag{5}$$

where the corresponding net output ($\widetilde{Y}$) can be expressed as follows:

$$\widetilde{Y} = Y - m_1 A = \left(1-\alpha^2(1-\tau)\right)Y. \tag{6}$$

Without the digital channel, the traditional channel operates as a monopoly with a constant markup value of $\frac{1}{\alpha}$, yielding a positive monopolistic profit of $\alpha(1-\alpha)(1-\tau)Y$. The amount of public services, which represents the business environment (A), decreases with the marginal cost m_1, implying that higher marginal costs for public services correspond to less service delivery via the traditional channel. Finally, the government's balanced budget, the production function (1), and optimality conditions (4) result in the following tax rate:

$$\tau = \frac{\alpha^2}{1+\alpha^2}. \tag{7}$$

Tax rate τ rises with the output elasticity of public services (α). The link between τ and α stems from the idea that α signifies firms' share of expenditure in public services, whereas $\tau = \frac{m_1 A}{Y}$ denotes the proportion of total public service provision cost in aggregate output.

The following proposition characterizes the equilibrium in the case without the digital channel:

Proposition 1. *Consider the case without the digital channel, where the government runs a balanced budget. Then, there exists a unique equilibrium in which τ is given by Eq. (7), P is given by Eq. (3), A is given by Eq. (4), and Y is given by Eq. (5).*

3.2. Specification introducing the digital channel

Considering the case in which the government launches the digital channel, the sequence of decisions between the agents changes correspondingly. In this case, the government designates the tax rate, digital channel expenditure, and the prices for public services before the firms make production decisions.

If the digital channel is implemented, while firm decisions are still characterized by Eq. (2), the price and total quantity of public services differ from the equilibrium without the digital channel. Specifically, the equilibrium conditions are summarized as follows[7]:

$$P = \frac{m_1(1-\theta)+m_2\theta}{\alpha}, \tag{8}$$

$$A = \left(\frac{\alpha}{m_1(1-\theta)+m_2\theta}\frac{\alpha}{1-\alpha}(1-\tau)\right)^{\frac{1}{1-\alpha}}\overline{L}, \tag{9}$$

$$Y = \frac{1}{1-\alpha}\left(\frac{\alpha}{m_1(1-\theta)+m_2\theta}\frac{\alpha}{1-\alpha}(1-\tau)\right)^{\frac{\alpha}{1-\alpha}}\overline{L}, \tag{10}$$

[7] Comparing to the previous case in which the government faces a total cost of $m_1 A$, now the total cost for the government to provide public services would be reduced to $(m_1(1-\theta)+m_2\theta)A$. The profit of the government now would be $PA-(m_1(1-\theta)+m_2\theta)A$ instead of $PA-m_1 A$.

$$\widetilde{Y} = Y - (m_1(1-\theta) + m_2\theta)A. \tag{11}$$

Compared with Eq. (3), the current government service costs in Eq. (8) decrease because now a fraction of θ firms are using the online platform to obtain public services, subsequently reducing the total cost of providing public services. Therefore, to maximize its performance, the government can set a lower government service price, which is a decreasing function of θ. The downward adjustment of price P indicates easier access to public services, which boosts the demand for services from Eqs. (4) to (9) at a given τ. However, since the traditional channel cannot be completely phased out by the government, as certain firms always prefer the traditional channel for various reasons, we impose a positive θ.

Under the presupposition of a balanced budget for the government, we determine tax rate τ so that $\tau Y = (m_1(1-\theta)+m_2\theta)A+\beta Y$, with the first and second terms on the right-hand side denoting the costs from producing public services and the ex-ante investment in the digital channel, respectively. This implies the following equilibrium tax rate:

$$\tau = \frac{\alpha^2+\beta}{1+\alpha^2}. \tag{12}$$

We next analyze the government's decision regarding whether to introduce the digital channel. The digital channel will only be established if the improved net output exceeds the channel's construction cost. Specifically, variables with the subscript D correspond to the case with government activity digitalization, and variables with the subscript 0 correspond to the case without government activity digitalization. Then, the condition can be formally expressed by $\widetilde{Y}_D - \widetilde{Y}_0 \geqslant \beta Y_D$. Therefore, the government will proceed with constructing the digital channel if the following condition is met:

$$\theta \geqslant \overline{\theta} \equiv \frac{m_1}{m_1 - m_2}\left[1-(1-\beta)^{\frac{1}{\alpha}}\right]. \tag{13}$$

Condition (13) provides insights into government decision-making under different circumstances. Because each firm only chooses one channel to acquire public services under price P, we can interpret θ as the extent to which firms support the digital channel. Given $\theta \geqslant \overline{\theta}$, the government will implement the digital channel because firms are supportive and the construction plan is feasible. In contrast, the government does not pursue the digital channel when $\theta < \overline{\theta}$ due to insufficient potential use. This indicates that the specification without the digital channel is a special case. The following proposition provides a formal summary of the above discussion.

Proposition 2. *When $\theta < \overline{\theta}$, the government decides not to launch a digital channel, and the equilibrium is characterized as in Proposition 1. Given $\theta \geqslant \overline{\theta}$, the government will implement the digital channel, and there exists a unique equilibrium in which τ is given by Eq. (12), P is given by Eq. (8), A is given by Eq. (9), and Y is given by Eq. (10).*

3.3. Comparative analysis

We measure the business environment based on the quantity of public services (A). Proposition 2 indicates that business environment and government activity digitalization are the result of general equilibrium. Our following empirical analysis treats business environment as the dependent variable, and the development of government activity digitalization is the main explanatory variable.

Formally, the difference in equilibrium business between cases with and without government activity digitalization is obtained as follows:

$$\ln A_D - \ln A_0 = \underbrace{\frac{1}{1-\alpha}\ln\frac{P_0}{P_D}}_{\text{Compliance Cost Effect}} + \frac{1}{1-\alpha}\ln\frac{1-\tau_D}{1-\tau_0}. \tag{14}$$

Eq. (14) indicates that the change in business environment originates from two channels. The first term on the right-hand side measures the impact of price changes in public services. Lower prices indicate lower costs to access public services for firms, so we refer to the first term as the *compliance cost effect* on the business environment. From Eqs. (3) and (8), the compliance cost effect is positive because $P_D < P_0$. Intuitively, launching the digital channel enhances competition in the public service market, resulting in a falling price and a growing demand for public services. The following corollary formally characterizes the compliance cost effect.

Corollary 1. *The implementation of the digital channel indicates that $\ln\frac{P_0}{P_D} > 0$ and signifies the existence of the compliance cost effect as it reduces compliance costs for firms, ultimately leading to an upsurge in the quantity of public services provided.*

The second term corresponds to the effect of tax rate changes on the equilibrium business environment. This effect is negative, as the government imposes higher tax rates to finance the digital infrastructure; however, the dominance of the compliance cost effect results in an overall increase in the business environment equilibrium.[8] The implications here also align with the literature on state capacity, which suggests that investing in capacity is at the heart of pursuing economic development (Besley and Persson, 2009). We summarize the net effect of government activity digitalization on the equilibrium business environment in the following corollary.

[8] Formally, we can verify this argument by proving $A_D > A_0$ in equilibrium using the two propositions.

Corollary 2. *Although the introduction of the digital channel indicates that* $\ln \frac{1-\tau_D}{1-\tau_0} < 0$ *and indirectly constrains the provision of public services, the compliance cost effect dominates, resulting in a net increase in the equilibrium business environment.*

In the subsequent section, we empirically assess and confirm the conclusions derived from our model using cross-country data. First, the implementation of government activity digitalization increases the equilibrium business environment. Second, government activity digitalization stimulates the business environment due to the compliance cost effect, demonstrating that the government provides public services to firms at lower costs by establishing the digital channel.

4. Data

This section describes the cross-country data that we use to test the predictions of our theoretical model in subsequent sections. We begin by presenting the business environment and government activity digitalization development measures, then describe the control variables. Finally, we present the variables that we used to test the underlying mechanisms.

Before delving into the details, we must note that our theoretical model elucidates how the implementation of government activity digitalization affects the business environment in equilibrium. Specifically, the introduction of online platforms entails a reduction in firms compliance costs for accessing public services, which stimulates the demand for such services. While direct observation of changes in firms demand for public services may be challenging, our theoretical model posits that the quantity of government services represents an equilibrium that is determined by both supply and demand sides. Consequently, as supply equals demand at equilibrium, our empirical design regarding how government activity digitalization affects the supply side of public service can also provide valuable insights on the impact of government activity digitalization on the business environment.

We measure the business environment using the ease-of-doing-business scores from the World Bank's *Doing Business* reports, covering 2003 to 2019.[9] These annual studies assess 10 regulatory dimensions and provide distance-to-frontier scores ranging from 0 to 100 for the overall business environment and each specific dimension. The scores are comparable across 190 countries and regions (referred to as countries hereafter), where higher scores indicate closer alignment with a superior business environment. Starting in 2010, these reports provide a composite index (the ease-of-doing-business score) that quantifies the overall regulatory environment. We calculate the scores from 2003 to 2019 using the 2010 methodology, detailed in Table A.1.

Our proxy for the level of government activity digitalization is the online service index, derived from the *E-Government Surveys* published by the Department of Economic and Social Affairs at the United Nations, which are published every one to three years. The online service index offers a crucial metric for assessing government activity digitalization development across countries, with cross-country evaluations of government activity digitalization progress for 2002, 2003, 2004, 2007, 2009, 2011, 2013, 2015, 2017, and 2019. This index is calculated based on responses to an Online Services Questionnaire that includes many questions to assess the digital features of each country's official website. The questionnaire evaluates whether websites have the capability to perform specific functions, such as online building permit or business license application. A higher online service index indicates greater availability of public services on the website.

Notably, the online service index only measures the coverage and quality of online public services and does not account for citizens' ability to access such services. The *E-Government Surveys* provide a more comprehensive measure, called the e-government development index, which is the weighted average of the online service index, the telecommunications infrastructure index, and the human capital index. The telecommunications infrastructure index captures the development and accessibility of telecommunications infrastructure, which serves as a robust representation of the ICT variable, while the human capital index quantifies residents' capability to use digital platforms. These indices are normalized to a range of 0 to 1 in the *E-Government Surveys*, which we rescale by a factor of 100 to facilitate the interpretation of our results. To incorporate the influence of ICT infrastructure and education attainment, we include the telecommunications infrastructure index and the human capital index as two covariates when using the online service index as the explanatory variable. Our results remain robust when we use the e-government development index as the explanatory variable. The methodology to compute online service and e-government development indices is presented in Table A.2.

We also collect data for an additional set of control variables that influence economic development and the business environment, encompassing the logarithm of per capita real gross domestic product (GDP), population growth rate, investment rate (share of gross fixed capital formation in GDP), trade openness index (share of imports and exports in GDP), and urbanization rate. GDP per capita, investment rates, and trade openness data are calculated based on Penn World Table 10.0, while the remaining control variables are obtained from the World Bank's World Development Indicators. Telecommunications infrastructure and human capital indices are also from the *E-Government Surveys*. Data on historical birth rates are extracted from the United Nations World Population Prospects published in 2019. The details of the definition of these variables are presented in Table A.3.

Furthermore, we extend our investigation to encompass two proposed underlying mechanisms, through which government activity digitalization influences the business environment. The first mechanism is firms' compliance costs to acquire public services. In particular, we calculate average scores across three aspects of compliance costs for each country, including the pecuniary cost, the average time to process a request, and the number of required procedures. These scores are obtained from *Doing Business* reports and range between 0 and 100, with a higher score indicating lower compliance costs, shorter precessing time, and fewer procedures. *Doing Business* reports provide scores on specific costs, time, and the number of procedures associated with starting a business, obtaining construction permits, acquiring electricity, registering property, and enforcing contracts. When calculating the average

[9] Publication of these reports was suspended after 2020.

Table 1
Descriptive statistics.

Variable	Number of countries	Observations	Mean	Standard deviation	Minimum	Maximum
Ease-of-doing-business score	167	1437	58.907	14.029	15.366	89.541
Online service index	167	1437	45.452	26.497	0	100
E-government development index	167	1437	50.209	21.373	0	97.580
Birth Rate from 1950 to 1955	167	1437	38.964	11.515	14.770	57.217
log GDP per capita	167	1437	9.199	1.217	5.527	12.023
Population growth rate	167	1437	1.428	1.587	−5.034	19.360
Investment rate	167	1437	0.228	0.088	−0.030	0.925
Trade openness index	167	1437	−0.069	0.165	−0.849	0.537
Urbanization rate (%)	167	1437	57.604	22.088	8.908	100
Telecommunications infrastructure index	167	1437	33.444	26.031	0.153	99.790
Human capital index	167	1437	72.125	20.060	0	100
Score on peculiar costs	167	1433	70.730	20.840	0	94.943
Score on time	167	1433	64.682	15.661	0	97.500
Score on procedures	167	1433	55.933	13.738	11.213	94.059
Total tax and contribution rate (% of Profits)	167	1161	44.412	32.083	7.400	339.100
Score on total tax and contribution rate	167	1161	75.635	23.910	0	100

scores on specific costs, time, and the number of procedures, we compute the simple average of the corresponding scores across the aforementioned categories, where higher scores indicate lower costs incurred by firms to access public services. The second mechanism considers government expenditure. As government expenditure is financed by firms' taxes in our theoretical model, we examine firms' tax and contribution rates, extracted from *Doing Business* reports. Specifically, the tax and contribution rate measures firms' average tax in the second year of operation as a proportion of commercial profit.

We collect data for 167 countries spanning 9 years between 2003 and 2019, covering 2003, 2004, 2007, 2009, 2011, 2013, 2015, 2017, and 2019.[10] Table 1 presents the descriptive statistics for the main variables in our empirical analysis. The ease-of-doing-business score, which serves as a proxy for the business environment, has a 58.907 average, with scores ranging from 15.366 to 89.541. The online service index and e-government development index have means of 45.452 and 50.209, respectively. The birth rate from 1950 to 1955 averages 38.964 births per 1000 individuals. The log GDP per capita has a 9.199 average, indicating substantial disparities in economic prosperity across the countries in our sample. The population growth rate also shows significant variation, with a mean of 1.428% and a range from −5.034% to 19.360%, pointing to diverse population dynamics. Investment and trade openness indices have means of 0.228 and −0.069, respectively. Urbanization is relatively advanced, with an average rate of 57.604%. There is also considerable variance in telecommunications infrastructure and human capital across different nations. Additionally, tax contributions also vary widely on a global scale. Overall, the data reflect significant international diversity in economic conditions and policy environment.

5. Effects of government activity digitalization on the business environment

This section presents our empirical strategy and cross-country evidence testing our model prediction on the digitalization of government activities proxied by the online service index and on the business environment proxied by the ease-of-doing-business score. We begin with a FE model to demonstrate the correlation between the online service index and the ease-of-doing-business score, after which we analyze the causality using two-stage least squares (2SLS) estimations. Finally, we conduct some robustness tests.

5.1. Fixed effects estimates

We begin by examining the correlation between the online service index and ease-of-doing-business score. Each point in Fig. 1 represents a country, the horizontal axis denotes the online service index, and the vertical axis reflects the ease-of-doing-business score. The figure confirms a positive correlation between the online service index and ease-of-doing-business score, indicating that enhanced government activity digitalization is associated with an improved business environment.

We next employ a FE model to examine whether government activity digitalization is correlated with the business environment. Our specification is as follows:

$$y_{it} = \gamma x_{it} + \boldsymbol{Z}'_{it}\psi + \mu_i + \lambda_t + \varepsilon_{it}, \tag{15}$$

where y_{it} is the business environment measure for country i in year t, and x_{it} denotes government activity digitalization. μ_i represents a full set of country FEs, whereas λ_t corresponds to a full set of year dummies. $\boldsymbol{Z}_{it}$ is a vector of the previously described control variables that could affect the business environment. ε_{it} is an idiosyncratic error term. The coefficient γ captures the effect of

[10] The complete list of countries that we examine is provided in Table A.4.

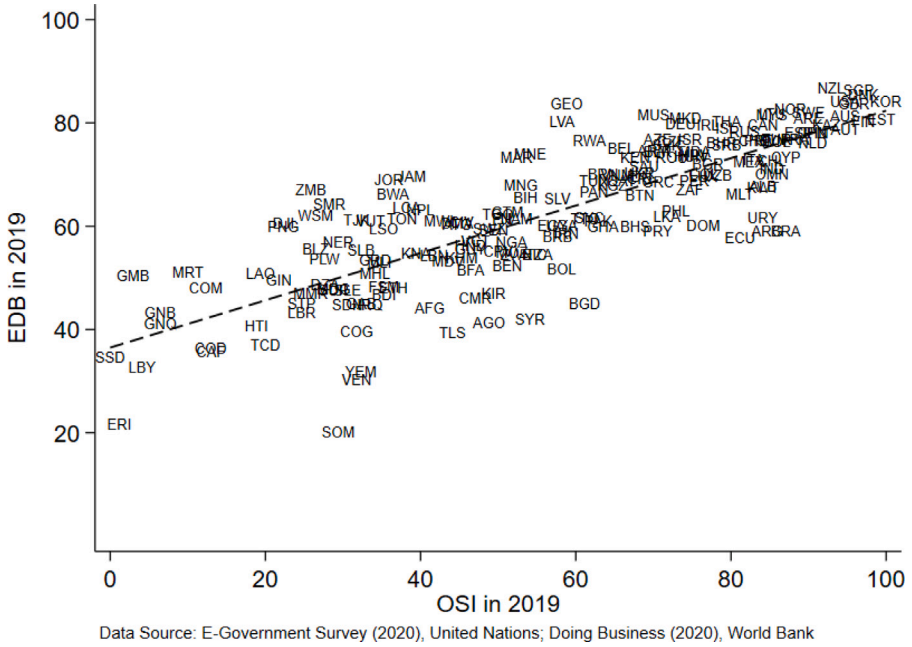

Fig. 1. Correlation between Online Service Index and ease-of-doing-business score in 2019.

government activity digitalization on the business environment. Our theoretical model predicts that improved government activity digitalization improves the business environment; therefore, we expect a positive estimation of γ.

Table 2 presents the FE estimates. In line with the predictions of our theoretical model, a significant positive correlation is revealed between government activity digitalization and the business environment. In columns (1) and (2), the business environment is quantified using the ease-of-doing-business score, while government activity digitalization is assessed using the online service index. We only introduce year and country FEs in column (1) and include a series of control variables in column (2). The estimated coefficient of the online service index is significantly positive in both columns. Specifically, ceteris paribus, the estimated coefficient for the online service index is 0.061. Between 2003 and 2019, the average difference in the online service index between the 75th and 25th percentiles was approximately 38.9, indicating that improving the online service index from the 25th percentile to the 75th percentile is associated with a 2.37 ($= 38.9 \times 0.061$) increase in the ease-of-doing-business score. Considering that the average gap in the ease-of-doing-business score between the 75th and 25th percentiles is 19.2, this development in the online service index can potentially close the gap by 12.3% ($= 2.37/19.2$). Among the control variables, the coefficients of GDP per capita, the Telecommunications Infrastructure Index, and Human Capital Index are significant. We repeat the FE regressions in columns (3) and (4) with the e-government development index as the core explanatory variable to confirm the robustness of our findings. The findings also demonstrate that government activity digitalization enhances the business environment, even when accounting for the extent to which firms are able to use technologies and the provision of telecommunication infrastructure. Moreover, since improving the business environment takes time, the environment in the previous period could influence the current period. To address this, we lag the ease-of-doing-business score as a control variable, presenting the results in column (5), and the benchmark findings remain robust.

The findings presented in Table 2 demonstrate a robust correlation between government activity digitalization and the business environment. Countries with widespread ICT use in government affairs exhibit a heightened ability to deliver services effectively. This preliminary evidence indicates that the digitalization of government activities can function as a strategic tool to help countries streamline administrative processes. It also establishes a more favorable environment for business activities. Consequently, these countries are more likely to attract and retain businesses, which drives economic growth and enhances competitiveness.

5.2. Two-stage least squares estimates

Although the results from the FE model show a positive correlation between government activity digitalization and the business environment, two challenges remain in interpreting causality. First, in alignment with the theoretical model, the implementation of government activity digitalization in a country is not exogenous as it depends on the anticipated uptake of online platforms for public service delivery. Should the government anticipate a lower adoption rate among citizens and firms for accessing public services through online channels, it can be unprofitable to allocate resources to such digital initiatives. Second, from an econometric perspective, the FE model introduces endogeneity concerns. This arises because higher economic development may not only arise from a superior regulatory environment, but also from a commensurate budgetary capacity to invest in government activity

Table 2
FE Estimates of government activity digitalization's effect on the business environment.

	Dependent Variable: Ease-of-doing-business score				
	(1)	(2)	(3)	(4)	(5)
Online service index	0.092***	0.061***			0.039***
	(0.019)	(0.018)			(0.012)
E-Government development index			0.240***	0.202***	
			(0.043)	(0.041)	
Lagged Ease-of-doing-business score					0.573***
					(0.028)
log GDP per capita		4.338***		4.337***	1.590**
		(1.204)		(1.203)	(0.704)
Population growth rate		−0.146		−0.132	0.072
		(0.117)		(0.121)	(0.076)
Investment rate		2.850		2.645	4.876**
		(3.932)		(4.015)	(2.201)
Trade openness index		1.461		1.625	4.115**
		(2.814)		(2.881)	(1.915)
Urbanization rate		0.127		0.118	−0.035
		(0.136)		(0.137)	(0.091)
Telecommunications infrastructure index		0.077**			0.033*
		(0.030)			(0.019)
Human capital index		0.127***			0.047**
		(0.037)			(0.021)
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
R-squared	0.528	0.564	0.540	0.560	0.728
Number of countries	167	167	167	167	167
Observations	1437	1437	1437	1437	1267

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

digitalization. In summary, due to endogeneity concerns, simply using the FE model might produce biased estimates and valid IVs are required.

To mitigate endogeneity issues, we use birth rates from the period immediately following World War II, specifically 1950–1955, as an IV for government activity digitalization. The validity of this IV requires relevance condition and exclusion restriction. First,1950–1955 birth rates are related to the demand for digitalized government activities from 2003–2019. The historical birth rates indicate the number of elderly individuals in each country in 2003–2019. For example, in 2019, countries with higher birth rates in 1950–1955 had more people aged 64–69 in 2003. According to the *E-Government Surveys*, a significant digital divide persists globally that is marked by disparities in the use of online government platforms across different demographics. The elderly population is particularly less engaged with the digitalization of government activities.

Digital platforms depend heavily on emerging technologies and devices, yet many elderly individuals have limited proficiency in using such technologies, and often face challenges in navigating digital tools such as computers, smartphones, and the internet. Adapting to new digital platforms can require substantial time and effort, which widens the gap in technological familiarity. As a result, the elderly tend to rely more on traditional service channels rather than transitioning to digital solutions. Additionally, the preferences and habits of older adults shape their demand for digitalized government activities. Many are accustomed to face-to-face interactions and handling paper documents and prefer conventional methods for accessing government services, such as telephone inquiries or in-person visits to government offices. This preference extends beyond habit and also involves issues of trust. Some elderly individuals may be skeptical of online transactions and digital information security, fearing personal data breaches or cyber fraud, which reduces their demand for digitalized government activities.

Consequently, societies with larger proportions of aging populations that had higher birth rates during 1950–1955 are expected to exhibit lower demand for online platforms. Therefore, when deciding the extent of digital platform development, local governments in such countries must anticipate fewer users. Therefore, the potential for government activity digitalization to enhance social welfare could be perceived as limited, resulting in the adoption of a more modest level of government activity digitalization.

Second, using 1950–1955 birth rates to construct IVs for the implementation of government activity digitalization also satisfies the condition of exclusion restriction. Birth rates during this period were primarily influenced by the reunification of soldiers with their families following the end of World War II. This fluctuation in birth rates was driven by post-war optimism, which was unrelated to the economic conditions of the time. Therefore, it is unlikely to affect the 21st-century business environment through economic variables that are unrelated to the population age structure.[11]

[11] 1950–1955 birth rates may indirectly shape the current business environment through labor supply effects on productivity and economic development. We control for this channel by incorporating several labor supply covariates in our regression analysis in Table A.11. Our main results persist after accounting for the labor dynamics, indicating birth rates shape the societal demand for government activity digitalization after accounting for labor market mechanisms. We thank the anonymous referees for pointing out this issue.

Table 3
2SLS Estimates of government activity digitalization's effect on the business environment.

	Dependent variable: Ease-of-doing-business score				
	(1)	(2)	(3)	(4)	(5)
Online service index	0.575***	0.568***			0.299***
	(0.143)	(0.143)			(0.089)
E-Government development Index			0.376***	0.305***	
			(0.120)	(0.111)	
Lagged Ease-of-doing-business score					0.545***
					(0.034)
log GDP per capita		−0.322		3.814***	−0.660
		(1.805)		(1.239)	(1.048)
Population growth rate		0.092		−0.113	0.142
		(0.237)		(0.121)	(0.151)
Investment rate		10.162*		3.468	8.074***
		(5.561)		(3.990)	(3.024)
Trade openness index		2.436		1.531	4.350**
		(3.596)		(2.818)	(2.148)
Urbanization rate		0.037		0.106	−0.026
		(0.206)		(0.139)	(0.115)
Telecommunications infrastructure index		−0.063			−0.031
		(0.054)			(0.031)
Human capital index		0.087			0.032
		(0.059)			(0.031)
Kleibergen–Paap rk Wald *F*-statistic	3.56	3.85	10.05	10.86	4.08
Overid *p*-value	0.25	0.25	0.00	0.00	0.00
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
Number of countries	167	167	167	167	167
Observations	1437	1437	1437	1437	1267

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table 3 presents the 2SLS estimates for the impact of government activity digitalization on the business environment. The first-stage estimations are shown in Table A.5. Columns (1)–(4) in Table 3 use the complete dataset spanning from 2003 to 2019. We construct a full set of interaction terms by interacting the 1950–1955 birth rates with year dummies, which are employed as IVs. A positive coefficient indicates that the digitalization of government activities in a country is positively correlated with corresponding progress in other countries. The coefficients of the online service index in columns (1) and (2) are statistically significant, indicating that government activity digitalization can improve the business environment. Notably, the coefficient is 0.568 in column (2), demonstrating that, ceteris paribus, a 1% decrease in the gap in the online service index with the frontier would lead to a reduction of 0.57% in the disparity in ease-of-doing-business score with the frontier. Considering the aforementioned difference between online service index and ease-of-doing-business score between the 75th and 25th percentiles, the impact of the 2SLS estimation results is greater than that of the FE model. Our findings also hold when using the e-government development index as the explanatory variable in columns (3) and (4). We also include the lagged ease-of-doing-business score as a control variable in column (5), and the estimates remain robust.

The causal relationship demonstrated above between government activity digitalization and the business environment implies that governments should strategically invest in digitalization to enhance their ability to deliver services effectively. Furthermore, countries with lower government activity digitalization can leverage these insights to adopt more advanced nations' practices from more advanced nations to improve their business environments. These insights emphasize the pivotal influence of digital transformation on modernizing public services and promoting balanced development, offering policymakers clear evidence to guide the implementation of government activity digitalization. A concern about weak IVs remains since the first-stage *F*-statistic is quite low (less than 10). Therefore, following Andrews et al. (2019) and Acemoglu and Restrepo (2022), we employ Anderson–Rubin (AR) tests and conditional likelihood ratio (CLR) tests. The findings reveal that the *p*-values from the AR and CLR tests are 0 in all regression models, rejecting the null hypothesis of the coefficient being 0, confirming the validity of our IVs.

To ensure the robustness of our conclusions, we conduct several robustness tests, presenting results in Tables A.6, A.7, A.8 and A.9. First, we investigate whether the baseline results are driven by specific countries by excluding samples from various continents, and the findings remain consistent. Second, we evaluate whether the results were influenced by particular time periods by analyzing only samples from after 2010, and once again, the results hold firm. Third, our data comprise an unbalanced panel since some countries lack the ease-of-doing-business score for specific years. For the robustness test, we include only countries with all nine years of observations and re-estimate our baseline regressions. The benchmark findings remain robust under this specification.

Finally, we incorporate additional variables concerning political systems in the baseline regression since these could impact the business environment. The results continue to demonstrate robustness across these different specifications.[12]

Another concern is that firms' decisions to establish operations in various countries and consequently engage with local government services are significantly influenced by the prevailing labor costs in those regions. To address this concern, we introduce labor costs into our empirical model as a control variable. We construct a labor costs index using labor income per worker based on employment, real GDP, and the share of labor compensation in GDP. The methodology for computing this index, along with the corresponding estimations, is detailed in Table A.10. The results reveal that the effect of government activity digitalization remains positive after controlling for labor costs.

Furthermore, the impact of government activity digitalization may differ between developed and developing countries. The livelihoods of populations in developing and developed countries differ, which can result in different paths by which post-WWII birth rates affect the age structure in current years. Furthermore, in developing countries, where the rule of law has not been fully established and bureaucratic malpractice can be more prevalent, the influence of government activity digitalization may be particularly significant. Therefore, we examine whether the effect of government activity digitalization differs based on these factors by differentiating between developed and developing countries, presenting the regression results in Table A.12. The results show the impact of government activity digitalization is greater in developing countries, which aligns with our expectations. Furthermore, we control for the frequency of natural disasters in the baseline results as a proxy for residents' living conditions in different countries. We obtain natural disasters data from the EM-DAT international disaster database of the Centre for Research on the Epidemiology of Disasters, University of Louvain. The results are presented in Table A.13, and the estimations remain robust.

The above findings demonstrate that government activity digitalization in public service provision can improve the business environment. The conclusion align with earlier research on the ICT adoption in the public sector that have shown improvement in public service efficiency and stimulation of economic activities (Shao and Liu, 2024). These findings also resonate with economic theories that highlight the benefits of investing in state capacities (Besley and Persson, 2010; Besley et al., 2022). Although adopting ICT requires investment, it provides significant advantages for bolstering a nation's service provision and capacity through various mechanisms, and the standardization of services across different platforms could be a key component.

6. Further analysis

Our baseline results indicate that the digital transformation of government activities significantly improves the business environment. This section presents additional findings that further support and extend our analysis. First, our theoretical model also posits two key mechanisms through which the digitalization of government activities enhances the business environment. The primary proposed mechanism is firms' reduced compliance costs when accessing public services such as fees and waiting times. The secondary proposed mechanism relates to firms' tax burdens. In the first subsection, we examine these two mechanisms in detail. We then analyze the effects of government activity digitalization in countries with varying levels of corruption and democracy to empirically explore whether the observed business environment improvement is attributable to the standardization of online and offline services. Additionally, our empirical approach assumes a significant increase in birth rates during 1950–1955 compared with earlier years; however, due to the lack of pre-1950 birth rate data, we cannot directly verify this assumption. To mitigate this concern, we investigate whether the impact of government activity digitalization is more pronounced in countries that were unaffected by World War II, as the post-war baby boom was partially driven by returning soldiers. Finally, while the evidence indicates that government activity digitalization positively affects the business environment, it remains unclear whether its impact is uniform across different dimensions of the business environment. Therefore, in the last subsection, we examine how digitalization influences various aspects of the business environment to provide a more nuanced understanding.

6.1. Mechanism tests

6.1.1. Government activity digitalization's effect on compliance costs

First, in the theoretical model, business environment improvement is partially attributed to reducing firms' total costs to obtain services (i.e., $\ln \frac{P_0}{P_D} > 1$). We investigate the relationship between government activity digitalization and firms' costs to access public services. We measure these costs using scores for average fees, time, and number of procedures required to obtain public services, as provided by *Doing Business* Reports. A higher score indicates lower compliance costs. Based on our theoretical model, we expect government activity digitalization to reduce firms' compliance costs, improving the business environment.

Table 4 presents the results. We calculate the simple average of scores for peculiar costs, time, and the number of procedures as the average cost index. Column (1) examines the effect of government activity digitalization on the average cost index. The significant coefficient of 0.360 at the 1% level indicates that each unit increase in government activity digitalization leads to a 0.360-unit decrease in the average cost index. We then conduct separate analyses to investigate the impact of government activity digitalization on peculiar costs, time requirements, and procedural steps in columns (2) to (4). A higher score reflects lower particular costs, shorter time requirements, and fewer procedures, and the results confirm that government activity digitalization causally reduces costs, time, and procedural steps when firms access public services, consistent with the predictions of our theoretical model.

[12] We also conduct unit root analysis to check the stationarity of the online service index and ease-of-doing-business score using the Fisher-ADF test. The *p*-values for all four tests — Inverse chi-squared, Inverse normal, Inverse logit t, and Modified inverse chi-squared — are 0.00, leading us to reject the null hypothesis that all panels contain unit roots. We appreciate the anonymous referees for bringing this issue to our attention.

Table 4
2SLS Estimates of government activity digitalization's effect on compliance costs.

Dependent variable:	Score on average costs (1)	Score on peculiar costs (2)	Score on time (3)	Score on procedures (4)
Online service index	0.360*** (0.125)	0.253* (0.142)	0.429** (0.206)	0.396*** (0.146)
Kleibergen–Paap rk Wald F statistic	3.85	3.85	3.85	3.85
Overid p-value	0.00	0.00	0.51	0.04
Anderson–Rubin Wald test p-value	0.00	0.00	0.02	0.00
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES
Number of countries	167	167	167	167
Observations	1433	1433	1433	1433

Note: Controls in Table 3 are included. * $p < 0.10$; * $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table 5
2SLS Estimates of government activity digitalization's effect on tax rates.

Dependent Variable:	Tax and contribution rate		Score on tax and contribution rate	
	(1)	(2)	(3)	(4)
Online service index	1.297 (0.833)		−0.286 (0.336)	
E-Government development index		1.140 (0.737)		−0.207 (0.371)
Kleibergen–Paap rk Wald F-statistic	2.18	11.39	2.18	11.39
Overid p-value	0.92	0.80	0.63	0.52
Anderson–Rubin Wald test p-value	0.19	0.02	0.15	0.08
Control Variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Country Fixed Effects	YES	YES	YES	YES
Number of Countries	167	167	167	167
Observations	1161	1161	1161	1161

Note: Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

6.1.2. Government activity digitalization's effect on tax rates

Although the effect on compliance costs dominates in improving the business environment, as suggested by our theoretical model, it also posits that government activity digitalization partially offsets this improvement by imposing higher tax burdens on firms ($\ln \frac{1-\tau_D}{1-\tau_0} < 0$). To examine this, we use the total tax and contribution rate and the score from *Doing Business* reports as a proxy for firms' tax burden. The estimated effect of government activity digitalization on tax rates is presented in Table 5.

Using the tax and contribution rate as the dependent variable and the online service index as the explanatory variable, column (1) reveals that government activity digitalization marginally increases the proportion of taxes in firms' commercial profits. This finding aligns with the predictions of our theoretical model. The results remain robust when we replace the explanatory variable with the e-government development index in columns (2) and (4) and when we substitute the dependent variable with scores on the tax and contribution rate in columns (3) and (4). We calculate these scores using the distance-to-frontier approach, which compares each country's tax and contribution rate against those of the country where firms experience the lowest tax burden. Consequently, a higher tax and contribution rate results in a lower score, reflecting a greater tax burden. The negative coefficients in columns (3) and (4) indicate a marginally significant increase in tax burdens that is correlated with government activity digitalization. This result is consistent with previous studies on tax collection via electronic systems, such as Bellon et al. (2022), which indicated that such systems make it more difficult for firms to avoid taxes.

Considering that the effect of government activity digitalization in Table 5 is marginally significant and relatively small in magnitude compared with its effect on compliance costs shown in Table 4, governments should continue to promote digitalization and encourage firms' adoption. The positive effects of government activity digitalization on firms, such as reduced compliance costs can overcome the increased tax burden and still support firm growth.

6.2. Online and offline services' uniformity

This subsection examines whether standardizing services across online and offline platforms is a channel through which government activity digitalization improves the business environment. Theoretically, unlike online platforms, which fully automate document collection and processing, offline platforms involve bureaucrats who oversee material collection and perform some degree of data processing. This autonomy can enable bureaucrats on offline platforms to exploit their positions for personal gain. For example, they may delay the provision of government services for firms that are unwilling to pay bribes or impose unnecessarily

Table 6
Government activity digitalization's effect on the business environment by corruption levels.

2SLS Estimates	Dependent variable: Ease-of-doing-business score			
	(1)	(2)	(3)	(4)
Online service index	0.508***	0.485***	0.366***	0.318***
	(0.086)	(0.097)	(0.103)	(0.102)
OSI × CPI in 2000	−0.043***			
	(0.012)			
OSI × CPI in 2005		−0.028**		
		(0.012)		
OSI × Polity in 2000			−0.004	
			(0.003)	
OSI × Polity in 2005				−0.003
				(0.003)
Kleibergen–Paap rk Wald *F*-statistic	3.36	4.64	2.77	2.31
Overid *p*-value	0.01	0.00	0.01	0.00
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES
Number of countries	87	149	150	150
Observations	779	1298	1310	1311

Note: Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses. OSI stands for online service index. CPI and Polity stand for corruption perceptions index and polity score respectively.

stringent documentation requirements. We argue that the introduction of online platforms has increased the transparency of government service processes, compelling offline bureaucrats to follow the same standardized procedures as those on online platforms, which reduces their autonomy and limits rent-seeking opportunities.

If this hypothesis holds, the effect of government activity digitalization is expected to be more pronounced in countries with higher corruption levels in the early stages. Prior to the adoption of government activity digitalization, bureaucrats in these countries were more likely to operate with low political accountability and engage in extensive rent-seeking behavior due to weaker regulatory frameworks. Consequently, digitalization of government activity is expected to result in a more significant reduction in rent-seeking opportunities for bureaucrats and more substantial business environment improvement.

To explore this conjecture, we categorize countries based on their corruption levels using the Corruption Perceptions Index (CPI) provided by Transparency International. CPI scores range from 0 (high corruption) to 10 (low corruption). We use the CPI scores from 2005 as proxy indicators for pre-existing corruption levels to evaluate the varying impacts of government activity digitalization across countries with different initial levels of corruption. Columns (1) and (2) of Table 6 introduce interaction terms between the online service index and countries' CPI in 2000 and 2005, respectively. The results reveal that government activity digitalization improves the business environment in countries with higher CPIs in the early years (i.e., 2000 or 2005) more effectively.

Additionally, the influence of government activity digitalization may vary between democratic and non-democratic nations. In nondemocratic countries, where political power is centralized, departments responsible for business regulation often operate with substantial autonomy and experience less stringent oversight from other government entities. However, with the introduction of government activity digitalization and its resultant transparency, these departments can no longer operate unchecked, as any misconduct is more visible and exposes them to potential repercussions from oversight mechanisms or other parties. As a result, the effect of government activity digitalization is expected to be more pronounced in non-democratic countries. To test this, columns (3) and (4) of Table 6 introduce interaction terms between the online service index and the polity scores of countries in 2000 and 2005, respectively. We find that in nondemocratic countries in the early years (i.e., 2000 or 2005), the online service index development marginally increases ease-of-doing-business scores. Table 6 also reports several key statistics. Although the Kleibergen–Paap rk Wald *F*-statistic is low, the Anderson–Rubin Wald test *p*-value is close to zero. According to Acemoglu and Restrepo (2022), the IVs remain valid despite these concerns. Furthermore, the Kleibergen–Paap rk LM statistic is small since the number of countries reporting data on corruption or polity scores in 2000 or 2005 is limited. Therefore, the results using IVs should be interpreted with caution.

In summary, the results in Table 6 indicate that the government activity digitalization improves the business environment by promoting standardized procedures across online and offline services. This finding aligns with our hypothesis that one mechanism through which government activity digitalization improves the business environment is by reducing bureaucratic autonomy and rent-seeking opportunities, as offline bureaucrats are compelled to adhere to the same standardized procedures as those of online platforms.

6.3. Baby boom measurements

Our identification strategy uses the sharp rise in birth rates during the baby boom; however, pinpointing the precise timing and scale of the baby boom presents challenges. First, due to the lack of complete and comparable birth and death rate data before 1950 in many countries, we are unable to verify whether a significant increase in birth rates indeed occurred between 1950 and 1955 in

Table 7
Government activity digitalization's effect on the business environment by World War II experience.

2SLS Estimates	Dependent variable: Ease-of-doing-business Score			
	(1)	(2)	(3)	(4)
Online service index	0.499***		0.497***	0.532***
	(0.111)		(0.119)	(0.130)
Online service index × World War II	−0.100*			
	(0.051)			
E-Government development index		1.226***		
		(0.296)		
E-Government development index × World War II		−0.130		
		(0.087)		
Kleibergen–Paap rk Wald *F*-statistic	2.94	2.75	4.86	4.36
Overid *p*-value	0.01	0.00	0.22	0.24
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00
Birth Rates as IV:	1950–55	1950–55	1955–60	1950–60
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES
Number of countries	167	167	167	167
Observations	1437	1437	1437	1437

Note: Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

some countries. Second, the baby boom period varied across countries, with some (e.g., the US) experiencing prolonged surges in birth rates. To address these issues, we conduct two analyses in this section.

First, although quantifying the exact rise in birth rates for some countries during and before 1950–1955 is challenging, the high birth rates during this period are commonly attributed to soldiers returning from World War II. Therefore, we compare the impact of government activity digitalization on the business environment between countries that participated in World War II and those that did not. The underlying assumption is that nations involved in World War II likely experienced a more pronounced baby boom, resulting in greater shifts in age structures by the 21st century, subsequently resulting in lower demand for digitalized government activities in the present day.

Therefore, we divide countries into World War II participants and nonparticipants. Table 7 presents the results. In column (1), we include the interaction between the online service index and World War II participation, and in column (2), we introduce the interaction between the E-Government Development Index and World War II participation. The results demonstrate that the evolution of government activity digitalization has had a smaller impact on the business environment of World War II participant countries compared with nonparticipant ones, as indicated by the negative coefficient of the interaction term. These results align with our expectation that the baby boom induced by World War II significantly altered the demographic structures of participating nations, which influenced the current demand for digitalized government activities. Moreover, this finding supports the notion that the baby boom was not driven by countries' endogenous policy choices but a systemic demographic shock attributed to the conclusion of World War II.

Second, while the baby boom was an exogenous shock, its timing varied across nations, making the use of birth rates from 1950–1955 as IVs potentially imprecise.[13] Therefore, to address these concerns, we construct IVs using average birth rates for the periods 1955–1960 and 1950–1960. The results in columns (3) and (4) of Table 7 confirm the robustness of our initial findings, demonstrating that the advancement of government activity digitalization continues to have a significant effect on the business environment, regardless of the specific timeline used to define the baby boom.

6.4. Government activity digitalization's impact on different business environment dimensions

Previous sections provide insights into the effects of government activity digitalization in a general regulatory environment. In this subsection, we investigate how government activity digitalization impacts various dimensions of the business environment using the distance-to-frontier scores derived from the 10 specific dimensions outlined in the *Doing Business* reports. In Table 8, the dependent variables in columns (1)–(10) are the scores for ten dimensions of the business environment, covering starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, and resolving insolvency. The estimates reveal a consistent trend, demonstrating that the implementation of government activity digitalization yields positive impacts across most business environment dimensions.

The presence of positive coefficients, particularly those that are statistically significant, indicates notable improvements in the business environment related to government activity digitalization. For example, the accessibility of services such as obtaining

[13] As evidenced by Van Bavel and Reher (2013), the baby boom occurred globally between the 1940s and 1960s, but the precise onset and decline of heightened birth rates differed across countries. We also show in Fig. C.2 that the high birth rates during the baby boom period were a global phenomenon, and the end of the baby boom likely extended beyond 1960.

Table 8
2SLS estimates of government activity digitalization's effect on different business environment dimensions.

Dependent variable:	Starting a business	Dealing with construction permits	Getting electricity	Registering property	Getting credit
	(1)	(2)	(3)	(4)	(5)
Online service index	0.208	0.418	1.426***	0.262**	−0.325
	(0.174)	(0.342)	(0.512)	(0.113)	(0.200)
Kleibergen–Paap rk Wald *F*-statistic	3.85	2.18	2.39	4.42	4.42
Overid *p*-value	0.00	0.03	0.27	0.02	0.00
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
Number of countries	1433	1161	998	1300	1300
Observations	167	167	167	167	167
Dependent variable:	Protecting minority investors	Paying taxes	Trading across borders	Enforcing contracts	Resolving insolvency
	(6)	(7)	(8)	(9)	(10)
Online service index	1.176**	1.186**	1.154*	0.001	−0.021
	(0.462)	(0.479)	(0.593)	(0.074)	(0.126)
Kleibergen–Paap rk Wald *F*-statistic	2.19	2.18	2.18	3.85	3.85
Overid *p*-value	0.20	0.33	0.35	0.16	0.31
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.14	0.05
Control variables	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
Number of countries	167	167	167	167	167
Observations	1169	1161	1161	1433	1433

Note: Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

electricity or making tax payments online can significantly reduce the time firms spend on these processes. Furthermore, digital platforms and government portals can facilitate easy access to information on investment regulations and financial statements, empowering minority investors to make informed decisions and reducing the risks of fraud or misinformation. These findings emphasize the importance of prioritizing government activity digitalization to strengthen specific business environment dimensions. The findings provide policymakers with crucial insights, enabling effective resource allocation and targeted interventions to enhance business environment dimensions in which digitalization has the most significant impact.

7. Conclusion

This study theoretically and empirically investigates the influence of government activity digitalization on the business environment. Our general equilibrium model demonstrates that pre-digital administrative systems imposed elevated operational burdens on firms due to discretionary bureaucratic practices in offline public service delivery channels. Therefore, government activity digitalization introduces standard procedural norms that are applicable across online and offline channels, reducing firms' compliance costs and enhancing public service accessibility. To validate our theoretical predictions, our cross-country empirical analysis using IV estimations confirms that the enhanced scope and quality of online government services causally improves the business environment through decreased compliance costs for firms. Moreover, this effect is particularly pronounced in developing countries. We propose three policy recommendations based on our findings.

First, policymakers should accelerate the digitalization of government activities. Our baseline findings demonstrate that incremental expansion of online public service portfolios yields measurable business environment improvement. Specifically, digital platforms should evolve beyond basic information portals to enable the digital processing of all services. For example, providing a business license renewal process that only requires sequential online form submission, rather than alternating between digital and physical interactions, can not only reduce transactional costs but also incur self-reinforcing efficiency gains through improved process transparency and predictability.

Second, governments should enforce standardized procedures across public service delivery channels. Our empirical findings reveal that inconsistent implementation across channels creates opportunities for offline bureaucrats' discretionary rent-seeking practices, which may negate the benefits of government activity digitalization. Governments could implement two complementary measures to eliminate such disparities. First, mandating regular training programs for offline staff and conducting unannounced audits of offline service documentation could verify adherence to established procedures in the offline channel. Second, publicizing standard service processes and establishing real-time citizen feedback mechanisms could further enable citizens to flag offline bureaucrats' noncompliant practices.

Third, developing countries should strategically optimize government activity digitalization. Our cross-country evidence demonstrates that these regions derive disproportionately large business environment improvements from government activity digitalization compared with advanced economies. We attribute this disparity to systemic deficiencies in traditional service delivery mechanisms, particularly in geographically isolated regions where infrastructure remains scarce. Considering infrastructure constraints, initial efforts could digitalize high-impact services such as business registration and tax compliance using simple applications that are compatible with basic mobile devices. Parallel investments in human capital should focus on training civil servants in digital workflow management, cybersecurity protocols, and data-driven performance monitoring to ensure effective use of technology in governance. By synchronizing infrastructure development with bureaucratic upskilling, developing countries can transform digitalization from a technocratic tool into an institutional mechanism for equitable service distribution, bridging critical digital divides.

Our study has three limitations that suggest potential directions for future research. First, government activity digitalization can alter organizational power structures and influence bureaucratic behavior, potentially affecting the business environment in ways our current data cannot capture. Future research could address this by obtaining internal government data to directly observe these organizational dynamics. Second, our study lacks micro-level data regarding how individual firms interact with digital government services, including which platforms they use and the associated costs. This limitation prevents us from identifying heterogeneous effects across different industries or firm types. If future studies can procure more detailed data via firm surveys or government data, researchers could distinguish effects across different industries to develop tailored policy recommendations for specific sectors. Third, our approach limits analysis of specific business practices such as production, investment, and profitability. With more comprehensive data on government firm interactions, future studies could explore their impacts across various business performance dimensions more comprehensively to quantify the social welfare gains from government digitalization.

CRediT authorship contribution statement

Xilu Chen: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Erqi Ge:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Xianxiang Xu:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Quan Zhou:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Extended model introducing corruption

Rather than assuming the government runs a balanced budget, consider a case in which the government can extract at most a fraction (denoted as ξ) of total taxation for its own consumption when determining the tax rate. The exogenous parameter $\xi \in (0, 1)$ can be interpreted as a measure of corruption that potentially influences government activity digitalization. This extension enables us to investigate the impact of corruption on the effectiveness of government activity digitalization in enhancing the business environment.

We first consider the scenario without government activity digitalization. All equations remain consistent with those presented in Section 3.1, with the sole exception of the government's budget constraint, which now takes the form $(1-\xi)\tau Y = m_1 A$, implying the following equilibrium tax rate:

$$\tau = \frac{\alpha^2}{1+\alpha^2-\xi}. \tag{A.1}$$

If $\xi > 0$, the above tax rate exceeds that presented in Eq. (7), indicating that firms in countries with high corruption will face higher tax rates compared with their counterparts in countries with low corruption.

We next examine the scenario with government activity digitalization, where the government's budget constraint becomes $(1-\xi)\tau Y = (m_1(1-\theta)+m_2\theta)A + \beta Y$, resulting in the following equilibrium tax rate:

$$\tau = \frac{\alpha^2+\beta}{1+\alpha^2-\xi}. \tag{A.2}$$

In addition to this tax rate exceeding that in Eq. (12), another crucial implication is that if either the digital infrastructure construction cost (β) or the level of corruption (ξ) is excessively high, the right-hand side of Eq. (A.2) may exceed 1. This suggests that the relative construction cost for digital infrastructure is so high that the government will be incapable of implementing government activity digitalization with the available tax revenue net of corruption and the cost of public service delivery.

Despite the potential alteration in the government's criteria for introducing the digital channel under high corruption levels, we also consider condition $\widetilde{Y}_D - \widetilde{Y}_0 \geqslant \beta Y_D$ to facilitate a comparison between the current model extension and our benchmark model. If the corruption level ξ remains constant before and after the implementation of digital channels, the government will proceed with digital infrastructure construction when the following condition is met:

$$\theta \geqslant \overline{\theta} \equiv \frac{m_1}{m_1-m_2}\left[1-\left(\frac{1-\beta-\xi}{1-\xi}\right)\left(\frac{(1-\beta)(1-\xi)+\alpha^2\xi}{1-\xi+\alpha^2\xi}\right)^{\frac{1-\alpha}{\alpha}}\right]. \tag{A.3}$$

The Eq. (A.3) indicates that corruption level ξ can influence the difficulty of the government in introducing digital channels, as reflected in the threshold $\overline{\theta}$. The elevated tax rates resulting from high corruption diminish the effectiveness of government activity digitalization in boosting overall output, necessitating a higher adoption rate of government activity digitalization for the government to proceed with its construction. Furthermore, the high tax rates also limit firms' public service demand, reducing the proportion of the cost of delivering public services in total output, which increases the share of net output in total output and offsets part of the difficulty of government activity digitalization. Therefore, the net effect of corruption on the government's decision to introduce digital channels remains ambiguous.

Finally, we scrutinize the effectiveness of government activity digitalization in boosting the quantity of public services in the extended model with corruption. The previous analysis is conducted assuming a constant level of corruption (ξ), but the level of corruption may decline following the introduction of government activity digitalization, which we demonstrated to be more effective in countries characterized by initially high CPIs (Martins et al., 2023). Assume that before the introduction of government activity digitalization, corruption in the economy is ξ_0, and after the introduction, corruption decreases to ξ_D. Formally, the effect of the introduction of government activity digitalization on an increase in government service levels can be expressed as follows:

$$\ln A_D - \ln A_0 = \frac{1}{1-\alpha}\ln\frac{P_0}{P_D} + \frac{1}{1-\alpha}\ln\frac{1-\xi_D-\beta}{1-\xi_0}. \tag{A.4}$$

The above equation indicates that, with other exogenous parameters held constant, countries with a higher reduction in corruption ξ subsequent to the introduction of government activity digitalization also experience a superior business environment improvement.

In summary, the integration of corruption into our baseline model emphasizes the impact of corruption on the extent to which government activity digitalization augments the business environment. High corruption levels not only exacerbate firms' tax burden but also directly impair the government's available tax income to afford the costs for government activity digitalization. Furthermore, corruption influences the government's decision-making regarding government activity digitalization, potentially constraining it to only implement digital channels when it can garner more robust support, which is measured by digital channel adoption rates. Finally, given that the introduction of government activity digitalization can mitigate corruption and that this effect is more pronounced in countries with higher initial corruption, our extended model posits that countries with initially higher corruption will also experience a more substantial business environment improvement following the government activity digitalization.

Appendix B. Additional tables

First-Stage Results:

Table A.5 presents the first-stage regression results of the 2SLS estimates, with column (2) serves as our baseline. With the exception of 2009, none of the coefficients for other years are significantly positive. Instead, the majority are significantly negative, which is consistent with our theoretical framework and empirical expectations. We posit that the cohort born from 1950 to 1955 influenced the demographic structure during our sample period. Considering that older individuals may find it more challenging to adeptly use online platforms for accessing public services compared with younger individuals, the proportion of population aging negatively affects societal demand for online public services. As a result, the demographic structure implies a negative correlation between early birth rates and government activity digitalization as shown in the coefficients for most of the IVs.[14]

[14] Since we predominantly employ the Online Service Index as the principal explanatory variable in our regression analyses, and given that the positive coefficient for "BirIV2009" is insignificant in the initial stage when utilizing the Online Service Index as the main explanatory variable as shown in Columns (1), (2), and (5) in Table A.5, we maintain that the potential positive effect of BirIV2009 does not compromise the validity of our IVs. The overall negative coefficients for years other than 2009 still support our IVs' validity and the broader implications of our demographic argument.

Table A.1
Calculation method of the Ease-of-doing-business score.

Topic	Indicator
Starting a business	Procedures, Time, Cost, Paid-in minimum capital
Dealing with construction permits	Procedures, Time, Cost, Building quality control index
Getting electricity	Procedures, Time, Cost, Reliability of supply and transparency of tariff index
Registering property	Procedures, Time, Cost, Quality of the land administration index
Getting credit	Strength of legal rights index (expanded from 10 to 12 points), Depth of credit information index (expanded from 6 to 8 points)
Protecting minority investors	Extent of disclosure index (0–10), Extent of director liability index (0–10), Ease of shareholder suits index (0–10), Extent of shareholder rights index (0–6), Extent of ownership and control index (0–7), Extent of corporate transparency index (0–7)
Paying taxes	Payments, Time, Total tax rate, Postfilling index
Trading across borders	Time to export: Documentary compliance, Border compliance; Cost to export: Documentary compliance, Border compliance; Time to import: Documentary compliance, Border compliance; Cost to import: Documentary compliance, Border compliance
Enforcing contracts	Time, Cost, Quality of judicial processes index
Resolving insolvency	Recovery rate, Strength of insolvency framework index

Note: The methodology for constructing the ease-of-doing-business score has been adjusted in different years, and this table reports the latest methodology.

Table A.2
Calculation method of the E-Government development index.

Topic	Indicator
Online service index	Constructed based on the online services questionnaire
Telecommunication infrastructure index	Estimated internet users per 100 inhabitants Number of mobile subscribers per 100 inhabitants Active mobile-broadband subscription Number of fixed broadband subscriptions per 100 inhabitants
Human capital index	Adult literacy rate The combined primary, secondary and tertiary gross enrollment ratio Expected years of schooling Average years of schooling

Note: The methodology for constructing the E-Government Development Index has been adjusted in different years, and this table reports the latest methodology.

Robustness Tests

We next conduct several additional tests to confirm the robustness of our results. First, we test whether the benchmark results are driven by certain countries. Referencing Acemoglu et al. (2001), we run our baseline IV regression using different samples of countries. Columns (1)–(5) in Table A.6 present the estimations after excluding countries from different continental groups. Specifically, we divide the countries into five continental groups, covering Africa, Asia, Europe, Oceania or North America, and South America or the Caribbean. The coefficients are all significant at the 1% level, with comparable magnitudes to those in Table 3.

Second, we test if our findings are affected by the timeframe of our sampled data. Specifically, considering the widespread formulation of government activity digitalization strategies after 2010, we narrow our focus to the post-2010 period in order to evaluate the contemporary impact of government activity digitalization on business environment. The significant positive coefficients in column (6) in Table A.6 indicate that government activity digitalization in recent years can improve the business environment. Therefore, our results are not driven by specific countries or periods.

Third, we include more controls in Table A.7. We consider variables related to political systems, as Acemoglu et al. (2019) suggested that political systems have a significant influence on economic development. For example, political characteristics can impact the efficiency and effectiveness of bureaucratic management, which affects the business environment. To control for the impact of political characteristics on the business environment, we introduce government effectiveness in column (1), regulatory quality in column (2), rule of law in column (3), leadership transitions in column (4), parliamentary democracy in column (5),

Table A.3
The definition and expected direction of variables.

Variable	Definition	Expected effects
Ease-of-doing-business Score	Ease-of-doing-business score is a measure that ranks countries based on the ease with which businesses can operate. It evaluates regulations affecting various aspects of the business environment, such as starting a business, obtaining permits, and protecting investors. The score ranges from 0 to 100, with higher values indicating a more favorable business climate.	
Online service index	Online Service Index is a measure that evaluates the extent and quality of online services provided by governments to their citizens.	Positive
E-Government development index	E-Government development index is a composite index that measures the readiness and capacity of countries to use information and communication technologies to deliver public services online. It assesses the development of government activity digitalization across three dimensions: the provision of online services, the telecommunication infrastructure, and human capital. The e-government development index is designed to help policymakers understand the state of government activity digitalization and to identify areas for improvement.	Positive
Log GDP per capita	The natural logarithm of GDP per capita, at chained PPPs (in mil. 2017US$).	Positive
Population growth rate	Population growth (annual %).	Positive
Investment rate	Share of gross capital formation at current PPPs	Positive
Trade openness index	Share of merchandise exports and imports at current PPPs.	Positive
Urbanization rate	Urban population (% of total population).	Positive
Telecommunications infrastructure index	Telecommunication Infrastructure Index is a composite measure that evaluates the quality and availability of telecommunication infrastructure in a country.	Positive
Human capital index	Human Capital Index is a composite measure that assesses the potential productivity of a country's future workforce by evaluating key indicators of human capital development.	Positive

and combine all variables in column (6).[15] In summary, all the columns present consistently significant and positive coefficients for the online service index at the 1% level, demonstrating that even after controlling for a range of variables, government activity digitalization has a significant impact on countries' business environment.

Fourth, we introduce the labor income per worker for each country into our estimations, and the results are shown in Table A.10. We calculate labor income per worker in country i using the real GDP, employment, and share of labor compensation in GDP, as provided by Penn World Table 10.0. Specifically,

$$\text{Labor Income per worker}_{i,t} = \frac{\text{Real GDP}_{i,t} \times \text{Share of Labor Compensation in GDP}_{i,t}}{\text{Employment}_{i,t}}.$$

The results are presented in Table A.10. In columns (1) and (2), we add labor income per worker to our baseline regressions as an explanatory variable. Our results remain robust in FE and 2SLS specifications, and the coefficients of the online service index are statistically significant at 1% level.

[15] Government effectiveness, regulatory quality, and rule of law are three important indicators that evaluate the overall governance and institutional framework of a country, as they reflect the government's ability to provide public services, support economic development, and uphold the rule of law. Countries with high scores in these indicators are more likely to have stable and conducive environments. We extract these variables from the World Bank. The leadership transition is a dummy variable derived from The Rulers, Elections, and Irregular Governance dataset. It is defined as 1 if a leadership transition occurred that year; otherwise, it is defined as 0. Similarly, parliamentary democracy is also derived from the same dataset and is equal to 1 if the country is a parliamentary democracy and 0 otherwise.

Table A.4
List of countries for analysis.

Country	Continent	Economic development status	Country	Continent	Economic development status
Angola	Africa	Developing	Kyrgyzstan	Asia	Developing
Albania	Europe	Developing	Lao People's Democratic Republic	Asia	Developing
Algeria	Africa	Developing	Latvia	Europe	Developing
Antigua and Barbuda	LAC	Developing	Lebanon	Asia	Developing
Argentina	LAC	Developing	Lesotho	Africa	Developing
Armenia	Asia	Developing	Liberia	Africa	Developing
Australia	Oceania	Developed	Lithuania	Europe	Developing
Austria	Europe	Developed	Luxembourg	Europe	Developed
Azerbaijan	Asia	Developing	Madagascar	Africa	Developing
Bahamas	LAC	Developing	Malawi	Africa	Developing
Bahrain	Asia	Developing	Malaysia	Asia	Developing
Bangladesh	Asia	Developing	Maldives	Asia	Developing
Barbados	LAC	Developing	Mali	Africa	Developing
Belarus	Europe	Developing	Malta	Europe	Developing
Belgium	Europe	Developed	Mauritania	Africa	Developing
Belize	LAC	Developing	Mauritius	Africa	Developing
Benin	Africa	Developing	Mexico	LAC	Developing
Bhutan	Asia	Developing	Mongolia	Asia	Developing
Bolivia	LAC	Developing	Montenegro	Europe	Developing
Bosnia and Herzegovina	Europe	Developing	Morocco	Africa	Developing
Botswana	Africa	Developing	Mozambique	Africa	Developing
Brazil	LAC	Developing	Myanmar	Asia	Developing
Brunei Darussalam	Asia	Developing	Namibia	Africa	Developing
Bulgaria	Europe	Developing	Nepal	Asia	Developing
Burkina Faso	Africa	Developing	Netherlands	Europe	Developed
Burundi	Africa	Developing	New Zealand	Oceania	Developed
Côte d'Ivoire	Africa	Developing	Nicaragua	LAC	Developing
Cabo Verde	Africa	Developing	Niger	Africa	Developing
Cambodia	Asia	Developing	Nigeria	Africa	Developing
Cameroon	Africa	Developing	North Macedonia	Europe	Developing
Canada	Northern America	Developed	Norway	Europe	Developed
Central African Republic	Africa	Developing	Oman	Asia	Developing
Chad	Africa	Developing	Pakistan	Asia	Developing
Chile	LAC	Developing	Panama	LAC	Developing
China	Asia	Developing	Paraguay	LAC	Developing
Colombia	LAC	Developing	Peru	LAC	Developing
Comoros	Africa	Developing	Philippines	Asia	Developing
Congo	Africa	Developing	Poland	Europe	Developed
Costa Rica	LAC	Developing	Portugal	Europe	Developed
Croatia	Europe	Developing	Qatar	Asia	Developing
Cyprus	Asia	Developing	Republic of Korea	Asia	Developed
Czech Republic	Europe	Developed	Republic of Moldova	Europe	Developing
Democratic Republic of the Congo	Africa	Developing	Romania	Europe	Developing
Denmark	Europe	Developed	Russian Federation	Europe	Developing
Djibouti	Africa	Developing	Rwanda	Africa	Developing
Dominican Republic	LAC	Developing	Saint Lucia	LAC	Developing
Ecuador	LAC	Developing	Saint Vincent and the Grenadines	LAC	Developing
Egypt	Africa	Developing	Sao Tome and Principe	Africa	Developing
El Salvador	LAC	Developing	Saudi Arabia	Asia	Developing
Equatorial Guinea	Africa	Developing	Senegal	Africa	Developing
Estonia	Europe	Developing	Serbia	Europe	Developing
Eswatini	Africa	Developing	Seychelles	Africa	Developing
Ethiopia	Africa	Developing	Sierra Leone	Africa	Developing
Fiji	Oceania	Developing	Singapore	Asia	Developing
Finland	Europe	Developed	Slovakia	Europe	Developed
France	Europe	Developed	Slovenia	Europe	Developing
Gabon	Africa	Developing	South Africa	Africa	Developing
Gambia	Africa	Developing	Spain	Europe	Developed
Georgia (Country)	Asia	Developing	Sri Lanka	Asia	Developing
Germany	Europe	Developed	Sudan	Africa	Developing
Ghana	Africa	Developing	Suriname	LAC	Developing
Greece	Europe	Developed	Sweden	Europe	Developed
Grenada	LAC	Developing	Switzerland	Europe	Developed/
Guatemala	LAC	Developing	Syrian Arab Republic	Asia	Developing

(*continued on next page*)

Table A.4 (*continued*).

Guinea	Africa	Developing	Tajikistan	Asia	Developing
Guinea-Bissau	Africa	Developing	Thailand	Asia	Developing
Guyana	LAC	Developing	Togo	Africa	Developing
Haiti	LAC	Developing	Trinidad and Tobago	LAC	Developing
Honduras	LAC	Developing	Tunisia	Africa	Developing
Hungary	Europe	Developed	Turkey	Asia	Developing
Iceland	Europe	Developed	Uganda	Africa	Developing
India	Asia	Developing	Ukraine	Europe	Developing
Indonesia	Asia	Developing	United Arab Emirates	Asia	Developing
Iran (Islamic Republic of)	Asia	Developing	United Kingdom of Great Britain and Northern Ireland	Europe	Developed
Iraq	Asia	Developing	United Republic of Tanzania	Africa	Developing
Ireland	Europe	Developed	United States of America	Northern America	Developed
Israel	Asia	Developing	Uruguay	LAC	Developing
Italy	Europe	Developed	Uzbekistan	Asia	Developing
Jamaica	LAC	Developing	Venezuela	LAC	Developing
Japan	Asia	Developed	Viet Nam	Asia	Developing
Jordan	Asia	Developing	Yemen	Asia	Developing
Kazakhstan	Asia	Developing	Zambia	Africa	Developing
Kenya	Africa	Developing	Zimbabwe	Africa	Developing
Kuwait	Asia	Developing			

Note: This table lists countries along with their continents and economic development status. LAC means Latin America and the Caribbean countries.

Table A.5
First-Stage regression results of the 2SLS Estimations.

	Online service index		E-Government development index		Online service index
	(1)	(2)	(3)	(4)	(5)
BirIV2003	−0.245**	−0.246**	−0.069	−0.046	
	(0.115)	(0.111)	(0.066)	(0.063)	
BirIV2004	−0.259**	−0.265**	−0.053	−0.032	−0.278**
	(0.109)	(0.108)	(0.065)	(0.062)	(0.109)
BirIV2007	0.017	0.016	0.045	0.057	−0.004
	(0.093)	(0.091)	(0.052)	(0.052)	(0.096)
BirIV2009	0.155	0.131	0.139***	0.151***	0.118
	(0.098)	(0.099)	(0.048)	(0.047)	(0.098)
BirIV2011	0.040	0.093	−0.058	−0.059	0.062
	(0.081)	(0.083)	(0.040)	(0.041)	(0.083)
BirIV2013	−0.045	−0.004	−0.100**	−0.110**	−0.030
	(0.109)	(0.107)	(0.045)	(0.045)	(0.108)
BirIV2015	−0.159**	−0.161**	−0.084**	−0.089**	−0.179**
	(0.079)	(0.079)	(0.035)	(0.035)	(0.080)
BirIV2017	−0.109	−0.118*	−0.026	−0.026	−0.119*
	(0.066)	(0.068)	(0.027)	(0.027)	(0.068)
Control variables	No	YES	No	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
R-squared	0.547	0.586	0.649	0.669	0.590
Number of countries	167	167	167	167	167
Observations	1437	1437	1437	1437	1267

Note: This table shows the first-stage estimation results for Table 3. The digitalization of government activities is assessed using the online service index in columns (1), (2), and (5) and the e-government development index in columns (3) and (4). In columns (1) and (3), only the country and year fixed effects are introduced. In columns (2) and (4), additional covariates are incorporated, including population growth, investment rate, share of industrial value-added in GDP, trade openness index and urbanization rate. The telecommunications infrastructure index and human capital index are also included as two controls in column (2). In colunm (5), the lagged variable of ease-of-doing-business score is included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.6
Government activity digitalization's effect on the business environment by different samples.

	Sample without Africa	Sample without Asia	Sample without Europe	Sample without Oceania or North America	Sample without South America or the Caribbean	Sample after 2010
	(1)	(2)	(3)	(4)	(5)	(6)
2SLS estimates	Dependent Variable: Ease-of-doing-business Score					
Online service index	0.894***	0.379***	0.484***	0.527***	0.581***	0.593***
	(0.306)	(0.101)	(0.143)	(0.140)	(0.148)	(0.197)
Kleibergen–Paap rk Wald *F*-statistic	1.53	4.52	3.21	3.69	3.95	2.83
Overid *p*-value	0.80	0.01	0.21	0.15	0.47	0.50
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES	YES
Number of countries	117	124	128	162	137	167
Observations	1010	1065	1094	1392	1187	834

Note: This table shows the robustness checks using different samples. Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.7
Government activity digitalization's effect on the business environment: Additional controls.

	(1)	(2)	(3)	(4)	(5)	(6)
2SLS Estimates	Dependent variable: Ease-of-doing-business score					
Online service index	0.538***	0.580***	0.587***	0.616***	0.620***	0.596***
	(0.139)	(0.143)	(0.145)	(0.154)	(0.155)	(0.151)
Government effectiveness	3.469**					2.489
	(1.546)					(1.963)
Regulatory quality		3.429**				2.475
		(1.575)				(1.955)
Rule of law			1.839			−1.144
			(1.511)			(1.815)
Leadership transition				−0.407		−0.305
				(0.562)		(0.544)
Parliamentary democracy					2.053	2.054
					(1.812)	(1.868)
Kleibergen–Paap rk Wald *F*-statistic	3.57	3.94	3.95	3.64	3.67	3.53
Overid *p*-value	0.19	0.19	0.27	0.34	0.35	0.22
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES	YES
Number of countries	167	167	167	166	166	166
Observations	1437	1437	1437	1428	1428	1428

Note: This table shows the robustness checks with additional controls. Controls in Table 3 are included. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Appendix C. Additional figures

Fig. C.1 illustrates the correlation between government activity digitalization in 2003 and 2019, proxied by the online service index, and crude birth rates from 1950 to 1955, revealing a negative correlation between the two indices, supporting our identification strategy.

Fig. C.2 shows the cumulative percentage change in the birth rate from 1950 to 1990, globally and across major continents. For each period t, the cumulative percentage change is calculated as follows:

$$\text{Cumulative Percentage Change}_t = \frac{\text{Birth Rate}_t - \text{Birth Rate}_{1950-55}}{\text{Birth Rate}_{1985-90} - \text{Birth Rate}_{1950-55}}$$

Fig. C.2 indicates that the global birth rate declined from 1950 to 1990, which was primarily concentrated after 1960. This suggests that the high birth rate during the baby boom period was a global phenomenon, and the end of the baby boom occurred after 1960.

Table A.8
FE estimations with balanced panel data.

	Dependent variable: Ease-of-doing-business score				
	(1)	(2)	(3)	(4)	(5)
Online service index	0.100***	0.067***			0.042***
	(0.021)	(0.019)			(0.013)
E-Government development index			0.251***	0.201***	
			(0.048)	(0.046)	
Lag of Ease-of-doing-business score					0.576***
					(0.029)
log GDP per capita		4.220***		4.284***	1.448**
		(1.239)		(1.241)	(0.678)
Population growth rate		−0.161		−0.152	0.119
		(0.130)		(0.132)	(0.089)
Investment rate		−0.759		−1.123	3.924
		(5.130)		(5.251)	(2.884)
Trade openness index		3.614		3.737	6.523**
		(4.086)		(4.192)	(2.842)
Urbanization rate		0.133		0.121	−0.048
		(0.151)		(0.152)	(0.097)
Telecommunications infrastructure index		0.070**			0.031
		(0.035)			(0.022)
Human capital index		0.122***			0.035
		(0.042)			(0.023)
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
R-squared	0.552	0.586	0.562	0.582	0.741
Number of countries	133	133	133	133	133
Observations	1197	1197	1197	1197	1064

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.9
2SLS Estimations with balanced panel data.

	Dependent variable: Ease-of-doing-business score				
	(1)	(2)	(3)	(4)	(5)
Online service index	0.576***	0.590***			0.339***
	(0.147)	(0.154)			(0.099)
E-Government development index			0.392***	0.303***	
			(0.110)	(0.098)	
Lag of ease-of-doing-business score					0.540***
					(0.038)
log GDP per capita		−0.613		3.728***	−1.131
		(1.934)		(1.235)	(1.153)
Population growth rate		0.064		−0.131	0.241
		(0.280)		(0.127)	(0.185)
Investment rate		9.233		−0.107	8.678**
		(7.350)		(5.258)	(4.293)
Trade openness index		4.344		3.424	6.731*
		(5.524)		(4.132)	(3.515)
Urbanization rate		−0.018		0.104	−0.075
		(0.239)		(0.154)	(0.133)
Telecommunications infrastructure index		−0.074			−0.041
		(0.061)			(0.035)
Human capital index		0.080			0.022
		(0.068)			(0.037)
Kleibergen–Paap rk Wald *F*-statistic	3.17	3.35	9.10	9.84	3.81
Overid *p*-value	0.29	0.36	0.00	0.00	0.12
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
Number of countries	133	133	133	133	133
Observations	1197	1197	1197	1197	1064

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.10
Government activity digitalization's effect on the business environment: Accounting for the labor costs.

	FE Estimates (1)	2SLS Estimates (2)
	Dependent variable: Ease-of-doing-business score	
Online service index	0.059***	0.449***
	(0.019)	(0.151)
Labor cost	−0.000**	−0.000
	(0.000)	(0.000)
Kleibergen–Paap rk Wald *F*-statistic	–	2.37
Overid *p*-value	–	0.08
Anderson–Rubin Wald test *p*-value	–	0.00
Control variables	YES	YES
Year fixed effects	YES	YES
Country fixed effects	YES	YES
R-squared	0.579	–
Number of countries	130	130
Observations	1135	1135

Note: This table shows the robustness tests to account for the labor costs. Controls in Table 3 are included. Column (1) shows the OLS estimation results, and column (2) shows the 2SLS estimation results. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.11
Government activity digitalization's effect on the business environment: Accounting for the labor dynamics.

	(1)	(2)	(3)	(4)	(5)	(6)
2SLS Estimates	Dependent variable: Ease-of-doing-business score					
Online service index	0.549***	0.577***	0.757*	0.742*	0.591**	0.539***
	(0.140)	(0.145)	(0.384)	(0.382)	(0.283)	(0.140)
Dependency ratio	0.048					
	(0.084)					
Unemployment rate		−0.121				
		(0.132)				
Health expenditure			−17.526			
			(26.910)			
Education expenditure				9.886		
				(22.238)		
Social protection expenditure					−49.184***	
					(16.888)	
Size of labor force						−3.705
						(4.085)
Kleibergen–Paap rk Wald *F*-statistic	3.79	3.95	1.07	1.03	1.16	3.72
Overid *p*-value	0.05	0.29	0.66	0.69	0.41	0.07
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES	YES
Number of countries	167	164	81	81	78	166
Observations	1437	1416	609	609	584	1416

Note: This table shows the robustness tests to account for the labor dynamics. Controls in Table 3 are included. We include the dependency ratio in column (1), unemployment rate in column (2), proportion of health expenditure in government spending in column (3), proportion of education expenditure in government spending in column (4), proportion of social protection expenditure in government spending in column (5), and labor force in column (6). * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.12
Government activity digitalization's effect on the business environment: Difference between developed and developing countries.

	Developed countries		Developing countries	
	(1)	(2)	(3)	(4)
2SLS Estimates	Dependent variable: Ease-of-doing-business score			
Online service index	0.092		0.602***	
	(0.073)		(0.184)	
E-Government development Index		0.053		0.394*
		(0.251)		(0.229)
Kleibergen–Paap rk Wald *F*-statistic	4.61	4.55	3.11	7.93
Overid *p*-value	0.10	0.34	0.64	0.00
Anderson–Rubin Wald test *p*-value	0.00	0.16	0.00	0.00
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES
Number of countries	28	28	139	139
Observations	249	249	1188	1188

Note: This table presents the regression results for developed and developing countries. In columns (1) and (2), the sample consists of developed countries. In columns (3) and (4), the sample consists of developing countries. In columns (1) and (3), the dependent variable is the online service index. In columns (2) and (4), the dependent variable is the e-government development index. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

Table A.13
Government activity digitalization's effect on the business environment: Controls concerning natural disasters.

	(1)	(2)	(3)	(4)	(5)
2SLS Estimates	Dependent variable: Ease-of-doing-business score				
Online service index	0.450***	0.445***	0.446***	0.456***	0.443***
	(0.142)	(0.141)	(0.141)	(0.145)	(0.139)
Earthquakes	0.251				
	(0.251)				
Floods		0.003			
		(0.165)			
Epidemics			−0.381		
			(0.432)		
Storms				−0.196	
				(0.175)	
All disasters					0.018
					(0.104)
Kleibergen–Paap rk Wald *F*-statistic	2.71	2.68	2.73	2.70	2.80
Overid *p*-value	0.09	0.09	0.10	0.11	0.09
Anderson–Rubin Wald test *p*-value	0.00	0.00	0.00	0.00	0.00
Control variables	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES
Number of countries	142	142	142	142	142
Observations	921	921	921	921	921

Note: This table presents the results considering the natural disaster variables. Controls in Table 3 are included. We include the number of earthquakes in column (1), the number of floods in column (2), the number of epidemics in column (3), the number of storms in column (4), and the number of all disasters in column (5). * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors are clustered at the country level and in parentheses.

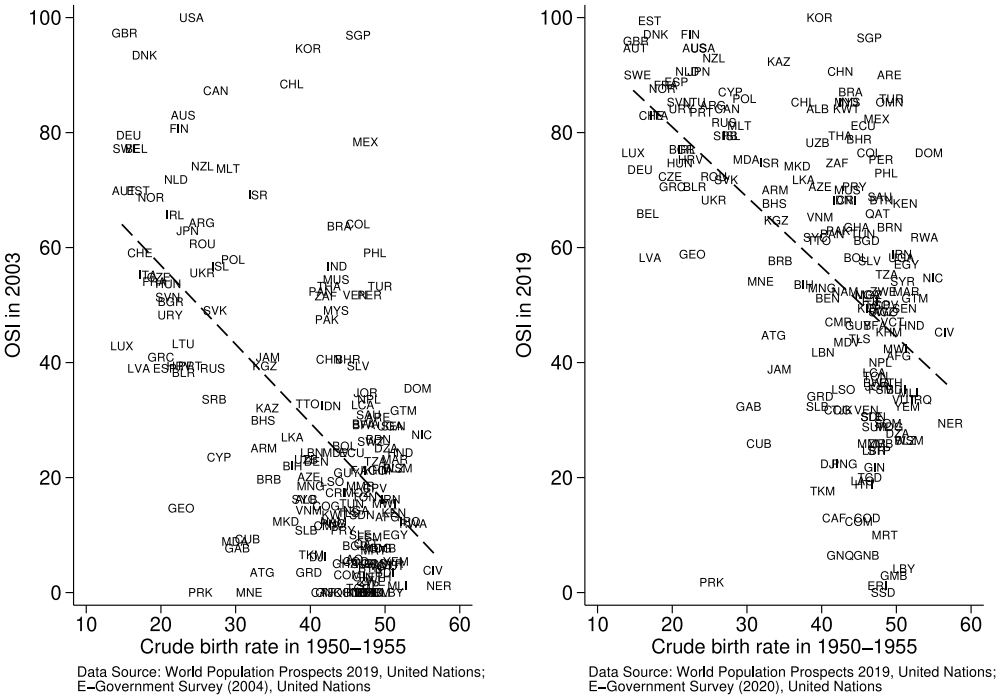

Fig. C.1. The relationship between online service index in 2003, 2009 and birth rates in 1950 to 1955.

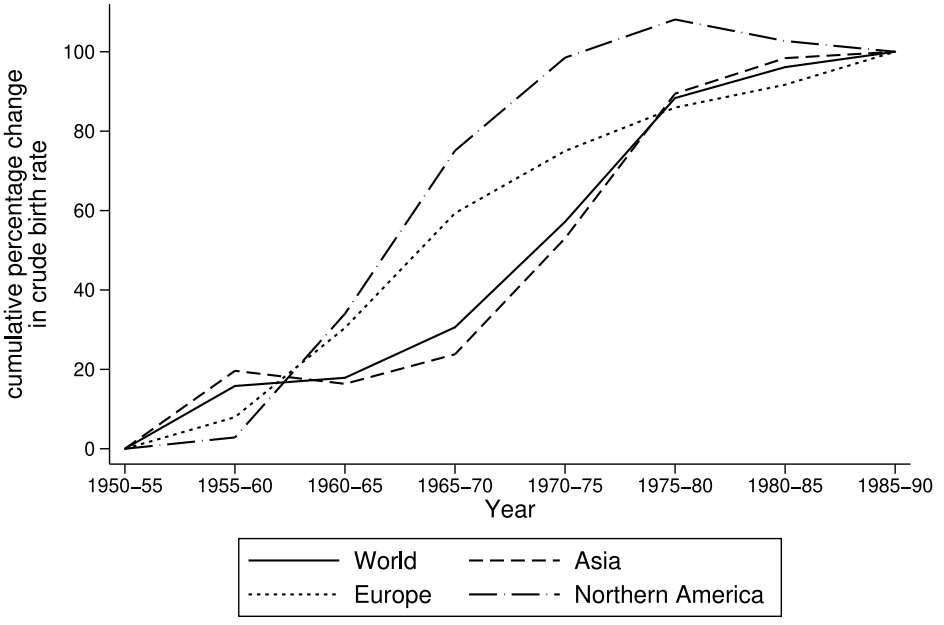

Fig. C.2. Cumulative percentage change in the birth rate from 1950 to 1990.

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