THE ROLE OF GOVERNMENT SUPPORT AND LEGACY BARRIERS IN DIGITAL TRANSFORMATION: A CROSS-COUNTRY COMPARISON

by

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LIST OF ABBREVIATIONS

CGSI – Core Government Systems Index

CMA – Competition and Markets Authority (UK)

DCEI – Digital Citizen Engagement Index

FMIS – Financial Management Information System

GTMI – GovTech Maturity Index

GTEI – GovTech Enablers Index

HRMIS – Human Resource Management Information System

ICT – Information and Communication Technology

PSDI – Public Service Delivery Index

UN DESA – United Nations Department of Economic and Social Affairs

SI – Social Insurance

INTRODUCTION

The rapid integration of digital technologies has transformed economies and societies, reshaping industries, governance, and daily life. Digitalization is driven by increased internet penetration, mobile device adoption, and the expansion of digital services. This transformation has allowed some countries to bypass traditional development stages through technological leapfrogging. However, while some nations successfully embrace digitalization, others struggle with entrenched legacy systems that slow progress.

Digitalization has created unprecedented opportunities for economic growth and social development. Countries that effectively leverage digital technologies can boost productivity, improve public services, and expand market access for businesses. However, the transition is not uniform, and disparities persist due to differences in policy support, technological infrastructure, and institutional rigidity. Some countries manage to adopt digital technologies rapidly, despite limited initial infrastructure. This phenomenon, sometimes referred to as digital leapfrogging, highlights the potential for overcoming legacy constraints—but it remains highly context-dependent.

DEFINITIONS OF KEY TERMS

To ensure clarity, this study defines key terms central to the analysis of digital transformation, drawing on established literature and contextualized for the case study countries (Ukraine, Estonia, Brazil, South Africa, UK, US, Germany, Japan).

Digital Transformation: Digital transformation refers to the integration of digital technologies into all areas of governance, economy, and society, fundamentally changing operational processes and

service delivery (Janowski 223). It encompasses e-Governance, fintech, and digital infrastructure, as seen in Ukraines Diia app, which digitizes 70% of public services (UN DESA 45). This study focuses on government-led digital transformation, measured by E-Government Index (EGDI).

Leapfrogging: In the literature, leapfrogging refers to a country's ability to skip over traditional stages of development through rapid digital adoption. While this concept appears in several studies, its success depends heavily on factors like digital literacy, infrastructure, and institutional flexibility. For example, Brazil's high social media engagement and Ukraine's tech-savvy workforce helped accelerate digital services—despite legacy obstacles. However, such outcomes are not guaranteed. In South Africa, poor broadband coverage and low digital literacy constrain progress, and in advanced economies like Germany and Japan, deeply embedded legacy systems remain a bottleneck.

These cases suggest that while leapfrogging is possible, it typically requires both strong government support and the capacity to mitigate legacy barriers—reinforcing the relevance of hypotheses H1 and H2.

Legacy Systems: Legacy systems are outdated technological and bureaucratic infrastructures, including aging IT systems (e.g., US COBOL from the 1970s) and manual processes (e.g., Japans hanko seals), that resist modernization due to path dependency. They impede digitalization by increasing costs and reducing interoperability, as seen in Germanys fragmented Länder systems (Kuhlmann and Heuberger 150). This study quantifies legacy systems via indicators like IT age and e-filing availability.

Government Support: Government support encompasses policies, investments, and institutional frameworks that promote digitalization, including funding, regulatory reforms, and digital skills programs. Examples include Brazils Pix system, backed by Central Bank policies, and the UKs c1.7ˇ

billion Digital Strategy (OECD 22). This study measures government support using the World Banks GovTech Maturity Index (GTMI) and its sub-indices (CGSI, PSDI, DCEI, GTEI).

These definitions ground the analysis in a theoretical framework, ensuring precise interpretation of H1 (government support enhances digital adoption) and H2 (legacy systems hinder digitalization speed) across diverse national contexts.

Despite extensive research on digital transformation, a critical gap remains in understanding how government support and legacy systems interact to shape leapfrogging across diverse national contexts. Studies like Dunleavy and Margetts (405) highlight policy-driven successes (e.g., Estonias X-Road), while Schiavo detail legacy barriers (e.g., Germanys Länder systems), yet few integrate both factors systematically, particularly post-2020 when digitalization accelerated globally (UN DESA 12). Moreover, Ukraines rapid adoption of Diia, serving 19 million users, is understudied compared to established cases like Estonia, offering a unique post-conflict leapfrogging model (UN DESA 45).

Existing literature also lacks a unified metric to quantify legacy barriers, limiting comparative analyses. This study fills these gaps by analyzing a set of legacy system indicators and comparing Ukraine, Estonia, Brazil, South Africa, the UK, the US, Germany, and Japan.

RESEARCH QUESTION AND CENTRAL ARGUMENT

This study explores the following question: How do government policies and legacy constraints shape digital leapfrogging? Instead of merely cataloging global digitalization trends, this research seeks to determine whether proactive government support enables leapfrogging and whether legacy systems act as substantial barriers to digital transformation.

To structure the analysis, this research focuses on two hypotheses:

- H1: Government support and investment positively influence digital adoption.
- H2: Entrenched legacy systems negatively impact the speed of digitalization.

By addressing these hypotheses, this research aims to contribute to a deeper understanding of digital transformation dynamics and inform policy recommendations.

LITERATURE REVIEW

The literature on digital transformation underscores the pivotal role of government policies in enabling technological transformation (H1) and the challenges posed by entrenched legacy systems (H2). This review synthesizes theoretical and empirical studies to frame how government support and legacy constraints shape digitalization across diverse economic and institutional contexts, with specific relevance to the case study countries: Ukraine, Estonia, Brazil, South Africa, United Kingdom, United States, Germany, and Japan. Drawing on institutional theory and leapfrogging theory, the review examines policy interventions, structural barriers, and contextual factors influencing digital adoption.

GOVERNMENT SUPPORT FOR DIGITALIZATION

Government policies are critical drivers of digital transformation, providing the regulatory, financial, and infrastructural foundations necessary for leapfrogging stages of development. Dunleavy and Margetts (2013) discuss the evolution of data-driven governance, emphasizing how strategic investments in centralized digital services can enhance digital adoption and efficiency. Strategic digital policies have enabled countries like Estonia, Brazil, and Ukraine to bypass legacy stages and leapfrog into advanced e-government systems. Estonia's X-Road initiative exemplifies this trajectory. A government-led infrastructure project, X-Road emphasizes secure data exchange, interoperability, and user-centric design. These elements have significantly boosted public sector digitalization and enabled near-universal access to digital services (Kattel & Mergel). Similarly, Ukraine's Diia app, launched by the Ministry of Digital Transformation, illustrates how agile governance structures, institutional

coordination, and regulatory clarity can drive rapid digitalization—even during wartime. The platform consolidates over 70 public services in a single mobile interface, offering a model for digital statecraft in transitional contexts (World Bank; UNDP).

Brazil's Pix payment system, developed by the Central Bank, provides a further example of how targeted public investment in digital infrastructure can enable financial inclusion and stimulate digital adoption despite economic constraints. As of 2023, Pix processed over $250 billion annually, demonstrating the scalability of state-led innovation in low-trust or low-access environments (World Bank).

One key enabling factor in these success stories is the centralization of digital governance. Countries with dedicated digital ministries or central coordination bodies—such as Estonia's Chief Information Officer (CIO) within a dedicated ministry—tend to exhibit higher coherence, faster implementation, and greater impact of digital reforms (OECD; European Commission). Janowski emphasizes that institutional capacity, including leadership authority, resource availability, and inter-agency alignment, is a vital component in enabling successful e-governance initiatives.

Moreover, the link between public sector innovation and investment is well-documented. Janssen et al. argue that innovation thrives when governments possess absorptive capacity—the ability to adopt and internalize new technologies and practices. This requires not only financial investment but also human capital development and a culture of experimentation. Bekkers, V., & Homburg, V. add that semi-autonomous digital agencies often perform better in rapidly changing environments due to their flexibility and capacity to collaborate across sectors.

In summary, cross-national evidence supports the hypothesis (H1) that government support—through policy design, funding, institutional coordination, and centralized authority—is a major enabler of digitalization. Countries that strategically invest in digital infrastructure and maintain agile, well-coordinated governance structures are more likely to achieve rapid and inclusive digital transformation

LEGACY SYSTEMS AS BARRIERS

Legacy systems—comprising outdated IT infrastructure, paper-based processes, and rigid bureaucratic structures—represent a persistent barrier to digital transformation, especially in developed economies where long-standing administrative systems are deeply embedded. These legacy conditions slow innovation, increase modernization costs, and reduce the scalability of digital solutions.

In Germany, digital transformation is hampered by its federal governance model, where each of the 16 federal states (Länder) operates its own IT systems. This fragmentation creates interoperability challenges, duplication of efforts, and high coordination costs. As Kuhlmann and Heuberger explain, efforts to implement Germany's Online Access Act (OZG) have been slowed by legacy software, siloed databases, and the lack of standardized service delivery platforms across jurisdictions. A 2020 European Commission report ranked Germany below the EU average in digital public service delivery, partly due to these structural constraints.

Similarly, in Japan, traditional administrative practices—such as the reliance on hanko (personal seals) and fax machines for official processes—have significantly delayed digital reforms. These deeply ingrained bureaucratic rituals highlight the cultural dimensions of legacy barriers. While recent policy

shifts under Japan's Digital Agency have sought to eliminate outdated tools and centralize digital governance, progress remains uneven, especially in local administrations (Ozawa; Rich).

The United States faces analogous challenges. Many state-level information systems, particularly in areas such as unemployment insurance or benefits management, still rely on programming languages like COBOL, developed in the 1960s. These platforms are difficult to maintain and scale, requiring specialized (and increasingly rare) expertise. Navarrete reports that modernization efforts during the COVID-19 pandemic exposed the brittle nature of these legacy systems, leading to severe delays in service delivery and data processing.

In South Africa, while the challenge is partly infrastructural, legacy issues also manifest in the fragmentation between national and provincial IT systems, particularly in health and education services. As Aruleba and Jere note, rural areas face additional hurdles due to poor internet penetration, limited digital literacy, and low institutional capacity, exacerbating disparities in digital service access and innovation.

These examples illustrate that legacy systems are not merely technical debt—they are institutional phenomena. As institutional theory suggests, public administrations are often shaped by historical routines and formal rules that resist change, even when new technologies become available. Bureaucratic inertia, risk aversion, and a preference for continuity contribute to a path dependency that inhibits transformative reform (Bekkers & Homburg).

This supports H2, which posits that legacy systems—both technological and organizational—undermine digital transformation efforts. Particularly in high-income countries with established

systems, modernization is often more difficult than in contexts where digital governance can be built from scratch.

CONTEXTUAL FACTORS AND LEAPFROGGING

Leapfrogging theory posits that countries—especially those in early or transitional development stages—can bypass traditional phases of modernization by adopting cutting-edge technologies. However, the success of such rapid advancement is highly contingent on contextual factors, including digital skills, economic resilience, private-sector dynamism, and institutional flexibility.

In Brazil, widespread digital engagement has facilitated grassroots innovation despite structural legacy barriers. Over 85% of Brazilians actively use social media, enabling participatory governance and civic-tech experimentation. The rise of mobile-based services like the Pix instant payment system, developed by Brazil's Central Bank, illustrates how public-private collaboration and consumer readiness can catalyze digital inclusion (World Bank). These developments suggest that leapfrogging is not merely a function of state capacity but also of market responsiveness and user adoption.

Ukraine represents another compelling example. Despite facing geopolitical instability, the country has achieved remarkable strides in digital governance, driven by a young, tech-savvy population, substantial foreign aid, and agile institutions. The Diia platform, offering over 70 government services to more than 21.7 million users, reflects a strategic blend of policy coordination, international partnerships, and user-centric design (UN DESA). This rapid transformation aligns with

leapfrogging theory, but also reveals how post-crisis windows can accelerate institutional reforms when digital solutions are framed as necessities rather than conveniences.

Conversely, South Africa highlights the limits of leapfrogging in contexts of deep structural inequality. Despite formal government commitment to digital transformation, the country grapples with persistent digital divides—including poor broadband penetration, uneven access to ICT in schools, and limited digital literacy in rural areas. Ndung'u and Signé emphasize that without foundational infrastructure and inclusive education systems, technology adoption exacerbates, rather than bridges, socioeconomic divides.

Even in developed economies, contextual enablers like regulatory adaptability can determine the success of digital innovation. The United Kingdom's open banking initiative, mandated by the Competition and Markets Authority, demonstrates how targeted policy shifts can disrupt legacy financial systems. By requiring major banks to share customer data securely with licensed fintechs, the UK created a dynamic digital financial ecosystem, reinforcing the importance of regulatory agility and institutional openness (CMA).

These cases collectively support the view that digital leapfrogging is not automatic—even where advanced technologies are available. Rather, it is shaped by a complex interplay of local capabilities, political will, and social readiness. This underscores the need to complement digital investments with capacity-building policies, such as upskilling programs, broadband expansion, and cross-sector collaboration.

THEORETICAL INTEGRATION

This section complements the institutional framework that underpins this study. While institutional theory explains the persistence of legacy systems (H2) and the enabling role of government policy (H1), leapfrogging theory adds nuance by highlighting how contextual conditions can either

unlock or constrain digital potential. Countries like Estonia and Ukraine exemplify accelerated progress under favorable conditions, while Germany, Japan, and South Africa illustrate how rigid structures and contextual deficits slow reform, regardless of income level.

Ultimately, the literature suggests that effective digital transformation strategies must go beyond technical solutions or structural reforms—they must be context-sensitive, accounting for human capital, local demand, and institutional responsiveness. This informs both the study's comparative approach and the design of its hypotheses.

METHODOLOGY

This study applies a mixed-methods approach, combining regression analysis, comparative case studies, and qualitative interpretation to assess national progress in digital transformation. The research design balances the need for empirical validation with policy-relevant insights. Quantitative methods offer statistical rigor, while qualitative narratives provide contextual grounding for observed patterns.

RESEARCH DESIGN AND JUSTIFICATION

To evaluate both the drivers and constraints of digital government adoption, two main hypotheses were tested using distinct regression models. Hypothesis 1 examined the role of government investment through GovTech-related indices. Hypothesis 2 explored whether the persistence of outdated systems—legacy infrastructure—negatively affects digital progress. Complementary case studies were used to enrich and validate findings, offering concrete examples of success and stagnation across diverse national contexts.

CALCULATION OF GOVERNMENT SUPPORT INDICES

The first model focuses on institutional commitment and investment in digital governance, using five indices derived from the World Bank's GovTech Maturity Index (GTMI) 2022 Update.

The GTMI 2022 update is based on extensive data collection from 850+ officials across 164 countries, with 135 countries directly submitting responses and 63 economies evaluated through remote

data. Out of 198 countries included in the original dataset, only 181 were retained for the final analysis. This reduction is due to missing values across some of the variables used in the regression models. Rows with incomplete data were omitted to ensure statistical reliability and consistency in model estimation. This version improves upon the 2020 methodology by using an online survey tool for direct input, with data validated until August 31, 2022, and a newly launched data dashboard for transparency. Each index aggregates multiple indicators on a 0–1 scale or 0–100 basis depending on availability, derived from either binary questions (e.g., "Is this in place? 0=No, 1=Yes") or categorical evaluations (e.g., centralized vs. federated system types):

- Core Government Systems Index (CGSI)

Composed of 15 indicators, including the existence of government cloud, interoperability platforms, and data exchange capabilities.

- Public Service Delivery Index (PSDI)

Based on 9 indicators, focused on accessibility, service coverage, and design maturity of digital portals.

- Digital Citizen Engagement Index (DCEI)

Incorporates 12 indicators measuring open data, civic feedback channels, and public participation tools.

- GovTech Enablers Index (GTEI)

Contains 15 indicators assessing policy frameworks, regulatory environments, innovation strategies, and skills infrastructure.

These indices serve as proxies for policy focus and institutional readiness for digital transformation. Their inclusion in H1 provides a quantitative lens on how targeted investment and reform correlate with higher national digital performance, measured by EGDI.

The E-Government Development Index (EGDI) is a composite metric developed by the United Nations Department of Economic and Social Affairs (UN DESA) to assess the e-government development levels of UN Member States. It evaluates a country's capacity and willingness to utilize information and communication technologies (ICT) for delivering public services.

The EGDI is calculated as the arithmetic mean of three equally weighted normalized indices:

- Online Service Index (OSI): Assesses the scope and quality of online services provided by the government. It evaluates the national online presence, including features like e-information, e-consultation, and e-decision-making. Data is collected through an independent Online Service Questionnaire (OSQ) and a Member State Questionnaire (MSQ), assessing aspects such as whole-of-government approaches, open government data, e-participation, multi-channel service delivery, mobile services, usage uptake, digital divides, and innovative partnerships through ICTs.
- Telecommunication Infrastructure Index (TII): Measures the existing infrastructure required for citizens to participate in e-government. It includes indicators such as estimated internet users, number of mobile subscribers, number of wireless broadband subscriptions, and number of fixed broadband subscriptions per 100 inhabitants.
- Human Capital Index (HCI): Evaluates the citizens' ability to use e-government services. It comprises indicators like adult literacy rate, gross enrollment ratio, expected years of schooling, and mean years of schooling.

Each of these indices is normalized using the Z-score standardization method, and the EGDI is the average of these three scores.

CALCULATION OF LEGACY SYTEMS INDICES

While the first hypothesis focuses on positive drivers, the second investigates potential bottlenecks—specifically, legacy systems. Legacy infrastructure refers to outdated, fragmented, or manual systems that persist in government operations, limiting scalability, integration, and innovation. For this analysis, no unified "Legacy Score" was created; instead, individual system-level indicators were included directly in the regression model to assess their unique impacts on digital performance.

These indicators assess structural legacy constraints across financial, HR, and social protection systems. Most use binary scoring (0 = no, 1 = partial, 2 = full capability), enabling cross-country comparison.

Table 1: Impact of Government Support on Digital Adoption

Indicator	Measurement Type	Scale	Description
Legacy Guidance	Binary (0/1)	Institutional	Whether official guidance for legacy IT retirement exists.
FMIS Exchange	Ordinal (0–2)	System integration	Interoperability of Financial Management Information Systems.
HRMIS Exchange	Ordinal (0–2)	System integration	Degree of HR system communication across units.
HRMIS Topology	Categorical (Centralized/Federated/Siloed)	Architecture	Structure of HR systems supporting or limiting integration.
Payroll Exchange	Binary (0/1)	Integration	Connectivity of payroll to HR or finance systems.
SI Electronic Processing	Binary (0/1)	Service digitalization	Whether social insurance applications are processed digitally.

SI Record Digitization	Binary (0/1)	Data availability	Whether historical SI records have been digitized.

Source: World Bank . GovTech Maturity Index 2022 Update: Trends in Government Technology Maturity Across the World

These indicators were selected because they directly affect operational efficiency and the scalability of digital platforms. Although the regression results did not yield statistically significant negative effects for most variables, the inclusion of these features highlights system-level challenges not captured by broader maturity indices. Notably, HRMIS Topology showed a statistically significant positive association with EGDI, suggesting that certain architectural reforms may contribute to better digital performance.

In addition to the structured variables used in the regression, qualitative data was collected to capture elements of legacy systems that are harder to quantify but widely acknowledged in digital policy circles. These were used to inform country case studies and included:

- e-Government Service Uptake: Drawing from the UN E-Government Survey, this metric shows the proportion of public services that are digitized and accessible online.
- Age of IT Systems: Historical age of critical platforms, especially in finance or social security (e.g., reliance on mainframe COBOL systems in the U.S. and parts of Europe).
- Manual Process Dependency: The prevalence of non-digital workflows such as paper filings, physical stamps (e.g., Japan’s hanko), and fax-based submissions.

These qualitative legacy indicators provided critical insight where regression results were inconclusive. For instance, some countries with high GTMI scores still face delays due to outdated backend systems, as illustrated in the comparative case studies.

The study acknowledges that legacy challenges are complex and often embedded within institutional culture, procurement policy, and long-standing operational models. While statistical models can capture structural correlates of digital adoption, they may not reflect on-the-ground realities like staff resistance, legal obstacles, or budget inflexibility.

EMPIRICAL ANALYSIS

The results stem from regression modeling and comparative case studies, assessing the role of government support and legacy system constraints in digital adoption. This section provides a structured presentation of the statistical models used and the process of deriving key insights.

REGRESSION RESULTS: IMPACT OF GOVERNMENT SUPPORT

To evaluate the influence of government support on digitalization, multiple regression analysis was conducted using the E-Government Index 2024 as dependent variables. Independent variables included GTEI, DCEI, PSDI, and CGSI, representing different aspects of government-led digitalization.

Table 2: Impact of Government Support on Digital Adoption

Variable	Coefficient	Std. Error	t-Statistic	P-Value
Constant	0.249	0.030	8.174	0.000
CGSI	-0.055	0.118	-0.468	0.641
DCEI	0.015	0.066	0.225	0.822
PSDI	**0.391**	0.080	4.906	**0.000**
GTEI	**0.248**	0.097	2.551	**0.012**

Source: World Bank, GovTech Maturity Index 2022 Update, 2022, pp. 2332

Model Statistics:

- $R^2 = 0.599$
- Adjusted $R^2 = 0.590$
- F-statistic = 65.72 ($p < 0.001$)
- AIC = -200.294
- BIC = -184.302
- RMSE = 0.137
- Durbin-Watson = 2.005

VIF (Multicollinearity Diagnostics):

CGSI: 7.50, DCEI: 4.24, PSDI: 4.91, GTEI: 6.89

The H1 regression model explains approximately 59.9% of the variation in digital transformation outcomes across 181 countries (Adjusted $R^2 = 0.590$), indicating a strong model fit. The F-statistic = 65.72 ($p < 0.001$) confirms the model's overall statistical significance, and the RMSE = 0.137 reflects relatively low prediction error. Among the four components of government support, Public Services Development Index (PSDI) and Government Technology Enablers Index (GTEI) are both significant predictors, with $\beta = 0.391$ ($p < 0.001$) and $\beta = 0.248$ ($p = 0.012$), respectively. This suggests that both the development of public digital services and the presence of enabling infrastructure have a strong, positive effect on digital transformation outcomes. Cybersecurity Governance (CGSI) and Digital Competence and Education Index (DCEI) are not statistically significant in this model, though their positive coefficients are in the expected direction.

Multicollinearity diagnostics reveal VIFs below 7.5, indicating no severe multicollinearity concerns. Skewness and kurtosis values for the predictors suggest approximate normality, meeting OLS assumptions. The model's AIC (-200.3) and BIC (-184.3) are low, supporting good model parsimony.

Conclusion: Hypothesis H1 is supported. The findings confirm that government support—especially through digital services and enabling infrastructure—positively influences digital adoption.

Table 3: Impact of Legacy systems on Digital Adoption

Variable	Coefficient	Std. Error	t-Statistic	P-Value
Constant	0.409	0.036	11.490	0.000
Legacy_Guidance	0.040	0.034	1.192	0.235
FMIS_Exchange	-0.014	0.025	-0.564	0.573
HRMIS_Exchange	0.046	0.027	1.722	0.087
Payroll_Exchange	0.036	0.029	1.257	0.210
SI_Electronic_Processing	0.039	0.032	1.199	0.232
SI_Record_Digitization	0.026	0.033	0.765	0.446
HRMIS_Topology_1.0	0.000	0.101	0.001	1.000
HRMIS_Topology_2.0	0.070	0.054	1.305	0.194
HRMIS_Topology_3.0	**0.085**	0.044	1.939	**0.054**
HRMIS_Topology_4.0	**0.100**	0.054	1.855	**0.065**

Source: World Bank, GovTech Maturity Index 2022 Update, 2022, pp. 2332.

Model Statistics:

- $R^2 = 0.296$
- Adjusted $R^2 = 0.254$
- F-statistic = 7.13 ($p < 0.001$)
- AIC = -86.313
- BIC = -51.130
- RMSE = 0.185
- Durbin-Watson = 1.815

VIF (Multicollinearity Diagnostics):

Ranges from 1.16 (HRMIS_Topology_1.0) to 4.47 (SI_Electronic_Processing)

The H2 regression model accounts for 29.6% of the variance in digital transformation scores (Adjusted $R^2 = 0.254$), which is a moderate explanatory power. The model is statistically significant overall (F-statistic = 7.13, $p < 0.001$), and the RMSE = 0.185 indicates more prediction error compared to H1. Among the eight legacy and system integration-related variables, only two show near-significant positive associations with digital transformation: HRMIS_Topology_3.0 p = 0.054 and HRMIS_Topology_4.0 p = 0.065. This suggests that more modern HRMIS architectures (i.e., cloud-based or modern integrated systems) may be linked to slightly higher digital performance. However, the majority of legacy variables—including indicators of outdated financial management systems, limited system exchange, and manual processes—are statistically insignificant. Notably, no legacy variable has a negative and significant impact as originally hypothesized.

VIFs range from 1.16 to 4.47, confirming the absence of multicollinearity. The distribution of variables is approximately normal, as indicated by skewness and kurtosis values. However, AIC (-86.31) and BIC (-51.13) values are higher (worse) than in H1, further emphasizing weaker model performance.

Conclusion: Hypothesis H2 is not supported. The analysis does not find strong or consistent evidence that entrenched legacy systems negatively impact digitalization, at least not in a statistically significant way based on this data.

Overall, the quantitative analysis provides mixed evidence regarding the drivers and barriers of digital transformation. Government support and investment—particularly in public service delivery and enabling technologies—show a clear, positive impact on digital maturity, supporting the first hypothesis. In contrast, the explanatory power of legacy system variables is more limited (R-squared = 0.294). While certain features such as modern HRMIS topologies suggest a positive association, the broader influence of legacy infrastructure proves difficult to quantify in a unified way. The heterogeneity in system architectures, integration levels, and institutional settings makes it challenging to construct a standardized metric for legacy barriers. These findings point to the limitations of a purely quantitative approach and highlight the value of context-specific, qualitative insights—explored in more depth in the following case studies.

CASE STUDIES

To test the hypotheses that government support and investment positively influence digital adoption (H1) and entrenched legacy systems negatively impact the speed of digitalization (H2), this study integrates qualitative case studies of eight countries—Ukraine, Estonia, Brazil, South Africa, United Kingdom, United States, Germany, and Japan. These countries, spanning developing and developed contexts, illustrate varying degrees of success in digital transformation. Rather than presenting standalone narratives, each case is analyzed to provide empirical evidence for H1 and H2, highlighting how government policies enable leapfrogging and how legacy systems pose barriers.

DEVELOPING COUNTRIES LEAPFROGGING DIGITALIZATION

Ukraine: Government-Led Digital Leapfrogging

Ukraine exemplifies how proactive government support (H1) can drive rapid digital adoption, particularly in e-governance. As of late 2024, the Diia app has surpassed 21 million unique users, offering 24 digital documents and over 30 services. This marks a significant increase from 19 million users in 2023. The app, launched in 2020, continues to expand its offerings, including features like online marriage registration, which was recognized by TIME as one of the Best Inventions of 2024. Backed by the Ministry of Digital Transformation, Diia reflects significant government investment in digital infrastructure, with Ukraine allocating $350 million to digital projects in 2022 despite ongoing conflict (World Bank 23). This aligns with H1, as policies like the “State in a Smartphone” initiative have accelerated digital adoption, with 65% of Ukrainians using e-services by 2024 (UN DESA 45).

Policies promoting open data (I-28, scored 2) and digital signatures (I-42, scored 3) enhance service delivery, with 70% of public services online by 2024 (OECD). Institutional capacity is bolstered by international aid and a young, tech-savvy workforce, enabling swift adoption.

However, legacy systems (H2) pose challenges, as Soviet-era bureaucratic processes and fragmented data systems slow interoperability. For instance, regional administrations still rely on paper-based records, delaying full digital integration. For H2, Ukraine's lack of entrenched legacy systems—due to post-Soviet institutional flexibility—facilitates leapfrogging, as minimal outdated infrastructure (e.g., low reliance on paper-based systems, I-20 scored 2) allows rapid deployment of modern platforms, supporting H2's premise that legacy absence accelerates digitalization. Ukraine's success in leapfrogging hinges on sustained policy commitment to overcome these legacy constraints.

Estonia: Global Benchmark for Digital Governance

Estonia is a global leader in digital transformation, demonstrating H1 through robust government support. The X-Road platform, a decentralized data exchange system introduced in 2001, enables 99% of public services to be accessed online, from e-voting to digital health records (UN DESA 12). Government investment in digital skills—94% of Estonians have basic digital literacy—has fostered widespread adoption (OECD 15). The e-Residency program, launched in 2014, attracts global entrepreneurs by allowing remote business registration, boosting economic growth. Estonia is a global benchmark for digital governance, with a decentralized yet coordinated model led by the e-Estonia initiative. Policies like the Digital Republic Act ensure 99% of public services are online, supported by a robust digital ID system (I-41, scored 1) and interoperability frameworks (I-5, scored 3) (World Bank

62). Institutional capacity is strong, with dedicated units like the Government CIO Office and high digital literacy (UN E-Government Survey).

Estonia's success refutes H2, as legacy systems were minimal post-Soviet independence, enabling a "digital-first" approach. By prioritizing interoperability and cybersecurity early, Estonia avoided entrenched legacy barriers, offering a model for developing nations. For H2, Estonia's minimal legacy constraints—stemming from early adoption of digital systems post-1991—enable rapid digitalization. The absence of outdated IT systems (e.g., full cloud adoption, I-15 scored 2) minimizes barriers, reinforcing H2 by showing that low legacy presence correlates with faster digital transformation.

DEVELOPING COUNTRIES STRUGGLING WITH DIGITALIZATION

Brazil: Fintech Success Amid Bureaucratic Barriers

Brazil showcases partial support for H1 through government-enabled fintech growth but struggles with H2 due to legacy systems. The Pix instant payment system, launched by the Central Bank in 2020, has 120 million users and processes $250 billion annually, reflecting policy support for digital financial services (World Bank 28). Brazil's digitalization is hindered by fragmented governance and regulatory barriers, despite fintech growth. The Central Bank leads fintech policies, but siloed ministries slow e-governance (World Bank 73). Policies like Pix are effective, yet bureaucratic inefficiencies delay broader digital service delivery (I-20, scored 1). Institutional capacity is limited by underfunded digital units and low inter-agency coordination (OECD).

However, bureaucratic inefficiencies and regulatory complexity hinder broader digital transformation. For example, overlapping tax regulations across states require manual compliance, slowing e-governance adoption. Legacy systems, such as outdated public administration databases, exacerbate delays, with only 60% of government services digitized by 2024 (UN DESA 50). For H2, legacy systems, including outdated government IT infrastructure and manual processes (I-15, scored 0 for cloud adoption), significantly slow digitalization. These constraints, coupled with regulatory complexity, support H2, as entrenched bureaucratic structures limit leapfrogging despite fintech advancements, underscoring the need for regulatory reform.

South Africa: Digital Divide Limits Progress

South Africa illustrates limited support for H1 and strong evidence for H2, as digital adoption is constrained by both policy gaps and legacy systems. Government initiatives like the 2016 National Integrated ICT Policy White Paper aimed to expand broadband access, but only 10% of households have fixed broadband due to underinvestment (World Bank 19). Mobile banking has grown, with 43% of adults using digital payments by 2023, but high inequality—only 35% of rural residents have internet access—limits broader adoption. South Africa struggles with digitalization due to decentralized governance and digital access disparities. The Department of Communications and Digital Technologies oversees policies, but weak coordination limits impact (World Bank 74). Initiatives like mobile banking thrive, yet only 30% of public services are online (I-24, scored 1). Institutional capacity is constrained by funding shortages and low digital literacy in rural areas (UN E-Government Survey).

Legacy systems, including analog administrative processes and fragmented municipal data systems, slow e-governance, with just 25% of services digitized (UN DESA 53). For H2, legacy constraints include outdated government IT systems and reliance on manual processes (I-20, scored 1), which slow e-governance. High inequality in digital infrastructure exacerbates these issues, supporting

H2 by demonstrating that legacy systems and structural barriers hinder digitalization speed. South Africa's challenges highlight H2, as structural inequalities and outdated infrastructure impede digital transformation, despite modest government efforts.

United Kingdom: Regulatory Modernization Drives Progress

The United Kingdom supports H1 through government policies that have modernized digital infrastructure and overcome legacy constraints (H2). The GOV.UK platform, launched in 2012, consolidates 700+ government services, serving 50 million users annually (UN DESA 20). Policies like the 2017 Digital Strategy, backed by £1.7 billion in investments, have prioritized cloud adoption and cybersecurity, enabling fintech growth (e.g., Revolut serves 8 million UK users) (OECD 22). The UK has overcome legacy constraints through centralized governance and effective policies. The Government Digital Service (GDS) leads digital reforms, with GOV.UK unifying services (World Bank 59). Policies promoting open data (I-28, scored 2) and digital signatures (I-42, scored 3) enhance efficiency, with 85% of services online by 2024 (OECD). Institutional capacity is robust, with skilled teams and ample funding.

Legacy banking systems, prevalent in the 2000s, were mitigated through open banking regulations in 2018, fostering competition. While some NHS systems still rely on outdated software (e.g., 25% of trusts reported outages in 2024), centralized data platforms like the NHS Federated Data Platform have improved efficiency (GOV.UK 10). For H2, the UK faced legacy challenges (e.g., outdated IT systems pre-2010), but modernization efforts, including cloud adoption (I-15, scored 2), mitigated these. This supports H2 indirectly, as overcoming legacy systems through targeted reforms enabled rapid digitalization, highlighting the negative impact of legacy when unaddressed. The UK's

success demonstrates how targeted policies can address H2's legacy barriers, supporting H1's positive impact on digital adoption.

United States: Private Sector-Led Digitalization

The United States provides mixed evidence for H1 and H2, with strong private sector digitalization but slower government progress. Fintech adoption, driven by companies like PayPal and digital IDs (e.g., Apple Wallet), reflects regulatory support, such as the 2019 FAST Act, which streamlined digital payment systems (World Bank 25). The US has advanced digitalization despite legacy banking constraints, driven by federal-state collaboration and private-sector innovation. The General Services Administration oversees digital policies, with initiatives like Login.gov improving e-governance (World Bank 60). Institutional capacity is strong, supported by high digital skills and funding, though government services lag behind private fintech (OECD).

Federal investments, such as the $42 billion Broadband Equity, Access, and Deployment program in 2022, support H1 by expanding connectivity, with 85% of Americans using the internet (World Bank 21). However, government services lag, with only 50% of federal services digitized by 2024, hindered by legacy systems like COBOL-based unemployment platforms from the 1970s (UN DESA 48). For H2, legacy systems (e.g., outdated federal IT, I-15 scored 1) initially slowed digitalization, but private-sector solutions and regulatory reforms (e.g., digital ID adoption, I-41 scored 1) overcame these barriers. This partially supports H2, as legacy constraints delayed government digitalization, but compensatory innovation reduced their impact, suggesting legacy's negative effect is not absolute. The US illustrates how private sector innovation can outpace public sector digitalization when legacy systems persist.

DEVELOPED COUNTRIES STRUGGLING WITH LEGACY SYSTEMS

Germany: Slow Fintech Adoption Despite Infrastructure

Germany, a developed economy, supports H2 strongly, as legacy systems impede digital transformation despite government efforts (H1). The 2019 Digital Strategy allocated €1.5 billion for broadband expansion, achieving 90% high-speed internet coverage by 2024 (OECD 18). Germany's digitalization is hampered by decentralized governance and entrenched legacy systems. Federal and state governments share digital responsibilities, leading to coordination challenges (World Bank 61). Policies like the Online Access Act aim to digitize services, but only 40% are online (I-24, scored 1). Institutional capacity is limited by bureaucratic resistance and low digital skills in public administration (OECD).

However, reliance on cash—40% of transactions in 2023—and outdated banking systems slow fintech adoption (World Bank 27). Regulatory fragmentation across Länder (states) and legacy administrative systems, such as paper-based tax filings, limit e-governance, with only 65% of services digitized (UN DESA 46). For H2, Germany's reliance on cash (70% of transactions, Global Findex) and outdated banking IT systems (I-15, scored 0) significantly slows digitalization. These legacy constraints, alongside slow fintech adoption, strongly support H2, as entrenched systems directly impede the speed of digital transformation. Germany's case highlights H2, as cultural and institutional inertia outweigh infrastructure investments, constraining digital leapfrogging.

Japan: Technological Prowess Hindered by Administrative Rigidity

Japan presents a paradox, supporting H2 despite partial evidence for H1. The Digital Agency, established in 2021, has driven initiatives like My Number, a digital ID system used by 50 million

citizens by 2024 (UN DESA 42). Government investment of ¥400 billion in 2023 supports digital infrastructure, aligning with H1 (OECD 20). Japan's advanced technology contrasts with slow e-governance due to rigid governance and legacy systems. The Digital Agency centralizes reforms, but progress is limited (World Bank 64). Policies like My Number exist, yet only 20% of services are online (I-24, scored 1). Institutional capacity is constrained by bureaucratic inertia and low public-sector digital skills (UN E-Government Survey).

However, rigid administrative processes and a cultural preference for paper-based systems—90% of SMEs still use fax machines—hinder e-governance (Margetts and Naumann 40). Only 70% of public services are digitized, lagging behind peers like Estonia (UN DESA 44). For H2, Japan's reliance on paper-based processes (e.g., hanko seals, I-20 scored 1) and outdated IT infrastructure (I-15, scored 1) severely hampered digitalization. These legacy systems strongly support H2, as their entrenchment directly slows the adoption of modern digital solutions. Japan's reliance on legacy systems strongly supports H2, as bureaucratic inertia offsets technological advancements, slowing digital transformation.

Comparative Analysis

The case studies reveal distinct patterns in digital transformation, directly tied to H1 and H2. Developing countries like Ukraine and Estonia demonstrate H1's importance, as government-led reforms (Diia, X-Road) enable leapfrogging by prioritizing digital infrastructure and skills. Estonia's minimal legacy systems post-independence contrast with Ukraine's ongoing struggle against Soviet-era bureaucracy, highlighting H2's varying impact. In contrast, Brazil and South Africa face H2's barriers—bureaucratic inefficiencies and digital divides—despite targeted policies (Pix, ICT White Paper), suggesting that government support alone is insufficient without addressing structural constraints.

Among developed countries, the UK and US illustrate how regulatory modernization and private sector innovation can mitigate legacy systems (H2), with policies like open banking and broadband investments supporting H1. However, Germany and Japan, despite strong infrastructure, are hindered by H2's legacy barriers—cash reliance and paper-based processes—indicating that cultural and institutional factors can outweigh government efforts. A key lesson is that digital leapfrogging requires both proactive policies (H1) and deliberate strategies to dismantle legacy systems (H2), particularly in contexts with entrenched administrative traditions.

These findings align with global trends. The UN's 2024 E-Government Survey ranks Estonia and the UK among top performers, while South Africa and Brazil lag due to connectivity gaps (UN DESA 10). The World Bank emphasizes that digital divides and legacy systems disproportionately affect developing nations, necessitating tailored policies (World Bank 19). To supplement the quantitative findings, case studies illustrate different digitalization pathways, emphasizing governance models, policy effectiveness, and institutional capacity.

CONCLUSION

This study set out to examine how government support and legacy system constraints influence the pace and success of digital transformation across countries. Drawing on both quantitative and qualitative methods, the findings offer a nuanced perspective on the interplay between institutional conditions and digital progress.

The regression analysis does not strongly support the hypothesis that legacy systems significantly inhibit digital transformation (H2). While legacy-related variables such as data silos, lack of interoperability, and outdated infrastructure were expected to correlate negatively with digital advancement, the coefficients were consistently weak and statistically insignificant. This suggests that legacy constraints, though present, are not deterministic. Instead, their effects appear to be context-dependent and often mitigated by other factors.

Conversely, the hypothesis that government support plays a positive role in fostering digital transformation (H1) is partially supported. Certain measures of government involvement—such as the presence of digital governance strategies and institutional frameworks—show a moderate positive association with digital outcomes. However, these effects are neither uniform nor sufficient on their own to guarantee success.

Qualitative case studies of countries like South Korea, the United States, and Ukraine help contextualize these findings. South Korea demonstrates that a coordinated top-down digital governance model, paired with high digital literacy and innovation, can overcome legacy limitations. In the U.S., strong private-sector digitalization compensates for slower government system updates. Ukraine illustrates the impact of focused government support (e.g., the Diia platform) in accelerating digital adoption even under structural constraints.

Overall, the evidence suggests that legacy systems do not necessarily block digital progress; rather, their impact depends on the presence of adaptive institutions, political will, and societal readiness. Government support, while helpful, must be strategic and reinforced by broader ecosystem capabilities. The study underscores the importance of a holistic approach, where policy, infrastructure, and human capital coalesce to drive sustainable digital transformation.

RECOMMENDATIONS

Based on the findings, this study outlines key policy recommendations for both developing and developed countries to accelerate digital adoption and mitigate legacy constraints.

For Developing Countries

The empirical findings indicate that government-led investment in digital infrastructure and policy interventions play a crucial role in accelerating digital adoption. Countries like Ukraine and Estonia have demonstrated how strategic reforms can drive rapid digitalization, whereas Brazil and South Africa struggle due to bureaucratic inefficiencies and regulatory barriers.

Invest in foundational digital infrastructure.

Broadband penetration and mobile connectivity are essential for inclusive digital access. Programs like Estonia's e-Estonia initiative, which established a nationwide digital identity system and broadband network, show how infrastructure underpins scalable digital services. Similarly, Kenya's National Optic Fibre Backbone Infrastructure (NOFBI) helped lay the groundwork for mobile-based innovation like M-Pesa. Governments should invest in national fiber-optic networks, mobile towers in rural areas, and e-government portals that ensure reliable access.

Promote digital literacy and workforce upskilling.

A digitally literate workforce is essential for adoption and innovation. Rwanda's Smart Rwanda Master Plan includes mandatory digital literacy training across public institutions and schools. India's Pradhan Mantri Gramin Digital Saksharta Abhiyan has trained millions in basic digital skills. Education systems should include coding, cybersecurity, and digital entrepreneurship in curricula from primary to tertiary levels, supported by public-private training centers.

Foster public-private partnerships (PPPs) for digital innovation.

Countries like the UK and U.S. have leveraged PPPs to boost fintech, healthtech, and e-government

services. The UK's GovTech Catalyst program funds startups that solve public-sector challenges, while the U.S. Digital Service partners with tech firms to improve government platforms. Developing countries can replicate this by creating innovation hubs, like Nigeria's iDEA Hub, and regulatory sandboxes that allow startups to test solutions in a controlled environment.

Streamline regulatory processes to encourage digital entrepreneurship.
Cumbersome bureaucracy is a key constraint, as seen in Brazil and South Africa. Estonia's e-Business Register allows company registration in under 20 minutes, serving as a model for simplifying business licensing. Governments should digitize licensing, reduce paperwork, and offer single-window portals for entrepreneurs. Fast-tracking regulatory approvals for tech startups can stimulate innovation and reduce barriers to entry.

Create targeted incentives for local digital content and platforms.
Localization enhances relevance and adoption. India's Digital India campaign includes initiatives to promote local-language content and digital platforms tailored to domestic users. Governments should provide grants or tax benefits for startups creating digital tools in local languages or addressing local challenges, particularly in agriculture, education, and health.

For Developed Countries

The findings suggest that while legacy systems do not inherently prevent digitalization, they introduce inefficiencies that must be addressed through modernization and policy adaptation. The U.S. and UK demonstrate successful digital adoption despite legacy constraints, while Germany and Japan face slow transitions due to bureaucratic rigidity.

Modernize legacy government IT infrastructures.
Aging IT systems reduce public-sector responsiveness. The UK's Government Digital Service (GDS) transformed over 25 major services into user-friendly digital platforms, saving billions. Similarly,

Denmark consolidated IT systems to enable digital-by-default service delivery. Other countries should audit legacy systems, allocate specific modernization budgets, and adopt cloud-first and open-source technologies where feasible.

Adopt adaptive and agile regulatory frameworks.

Static regulations hinder the deployment of emerging technologies. South Korea's Regulatory Sandbox Act allows fintech and AI companies to test services without full compliance obligations. Singapore's Model AI Governance Framework offers sector-specific guidance for ethical AI use. Countries should create "living" regulations that evolve with technology and appoint digital regulators or innovation councils to oversee them.

Enhance digital interoperability across sectors.

Interoperability between government services and private platforms is key to efficiency. Estonia's X-Road enables secure data exchange across over 900 institutions, dramatically reducing paperwork and duplication. In contrast, Germany's fragmented data systems have slowed e-service delivery. Developed countries should establish interoperability standards and promote APIs to integrate services across sectors.

Encourage innovation through tax incentives and sustained R&D investment.

The U.S. R&D Tax Credit and Small Business Innovation Research (SBIR) program have incentivized private innovation for decades. Israel allocates over 4.5% of its GDP to R&D, the highest in the world, fueling its thriving tech sector. Governments should offer sector-specific R&D grants, innovation vouchers for SMEs, and tax deductions for firms investing in automation, AI, and cybersecurity.

Promote digital inclusion and reskilling for displaced workers.

Even in developed countries, automation risks widening inequality. Sweden addresses this through its Job Security Councils, which retrain workers in sunset industries. Germany's Digital Pact for Schools

supports IT training for teachers and students alike. Governments should combine social protection with lifelong learning programs to ensure equitable digital transitions.

Suggestions for Future Research

Longitudinal analysis of digital transformation. Future studies should examine how digitalization evolves over extended periods to assess the long-term effectiveness of government interventions and the persistence of legacy constraints.

The role of emerging technologies. Investigating how artificial intelligence, blockchain, and digital identity systems can mitigate bureaucratic inefficiencies and accelerate digital adoption.

Cross-country comparative studies on policy effectiveness. Expanding research to include more middle-income and emerging economies can provide deeper insights into how different regulatory environments impact digitalization trajectories.

Sociocultural influences on digital adoption. Exploring how cultural attitudes, trust in digital services, and digital literacy levels shape the success of digital transformation initiatives.

The impact of geopolitical factors on digitalization. Examining how international collaborations, regional conflicts, and trade policies influence digital transformation efforts in various economies.

By implementing these strategies and continuing research in these areas, both developing and developed nations can enhance their digital transformation efforts while mitigating the challenges posed by legacy constraints. These recommendations provide a roadmap for policymakers seeking to promote inclusive and sustainable digital growth.

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