Online appendix for "Enhancing Efficiency of Public Expenditure Through GovTech"

A. Variables: Definition and Sources

Measure	Definition	Source
Panel A. GovTech Maturity Index (GTMI, composite scores in range 0-1)		
GT1: Core Government systems	Captures modernization and integration of government fiscal systems through cloud services, interoperability frameworks, and digital platforms. Covers tax administration, treasury and budget operations, public procurement (e.g., e-procurement), public investment management, and human resource management.	World Bank GTMI
GT2: Public service delivery	Measures the presence and maturity of government's online service portals and digital public services (e.g., tax filing, e-payment, customs). Accounts for the simplicity, transparency, and universal accessibility of online services, as well as demand-side affordability (mobile access, free open-source applications).	World Bank GTMI
GT3: Citizen engagement	Captures citizens' online participation and feedback in policymaking through CivicTech tools (e.g., complaint-handling mechanisms, open data portals). Also reflects government responsiveness (e.g., response time, information disclosure, accountability tools).	World Bank GTMI
GT4: GovTech enablers	Captures a country's progress in legal and institutional foundations for digital reforms. Includes 16 indicators on data governance, right-to-information (RTI) law, data protection and privacy, digital ID, electronic signatures, ITU cybersecurity index, citizen digital skills and training, innovation strategies, and private sector participation.	World Bank GTMI

Panel B. GTMI Sub-indices (binary indicators)		
GovTech institutions	Presence of a government body dedicated to digital transformation and whole-of-government coordination of services (0/1).	World Bank GTMI
TSA-FMIS integration	Centralized Treasury Single Account (TSA) at Central Bank integrated with FMIS. Automated data exchange through fully operational IT system covering >75% of revenue and expenditure transactions (0/1)	World Bank GTMI
E-procurement platform	Existence of an e-procurement portal that supports public procurement, including tender announcements and publication of contract information (0/1)	World Bank GTMI
Public investment management system	Existence of public investment management system (PIMS) that digitalizes the whole project cycle: submission, review, approval of project proposals, execution, and monitoring of the projects (0/1)	World Bank GTMI
Panel C. Other Variables		
Enhanced Digital Access Index (EDAI)	Composite index (0–100). Summarizes both demand-side (affordability, education, internet usage) and supply-side (ICT infrastructure, quality of services) dimensions of digital access.	Alper and Miktus (2019)
Open Budget Index (OBI)	Average score (0–100) of survey questions related to public access to comprehensive and timely budget documents (including pre-budget statement, executive's proposal, enacted budget, citizens' budget, in-year, mid-year, year-end, and audit reports).	International Budget Partnership (IBP)'s Open Budget Survey
Public Participation Index (PPI)	Average score (0–100) of survey questions related to public participation in budget decision-making, oversight, and monitoring.	IBP Open Budget Survey

B. Summary Statistics for the Cross-sectional Analysis (Section 4.2.1)

Tables A.1 and A.2 report the summary statistics of the World Bank's GTMI aggregate index and the PEFA index used in Section 4.2.1. As Appendix A described, the aggregate GTMI consists of four components.

Core government systems (GT1) scores are high in Advanced Economies (AEs, mean=0.8), which reflects the near-complete modernization and integration of fiscal systems into digital platforms. In contrast, Emerging Market and Developing Economies (EMDEs) display much lower average values (mean=0.59), underscoring the gap in government technology adoption.

Public service delivery (GT2) shows a similar pattern: online services such as e-tax filing and digital payments are widespread in AEs (mean=0.91) but remain less common in EMDEs (mean=0.66).

Citizen engagement (GT3) in budgetary processes is less prevalent overall, with average of 0.75 in AEs and 0.47 in EMDEs (0.75 vs 0.47, on average). Similarly, **GovTech enablers** (GT4) indicates a substantial gap in the maturity of legal, regulatory, and institutional frameworks that support digital reforms. The inter-quartile ranges of citizen engagement index and GovTech enabler index are wide, pointing to large cross-country heterogeneity.

Table A.1: Aggregate GTMI Index (by Income Groups)

	AEs						EMDEs					
	N	Mean	Std dev	P25	P50	P75	N	Mean	Std dev	P25	P50	P75
GT1: Core Government System	17	0.80	0.10	0.76	0.79	0.86	103	0.59	0.21	0.43	0.58	0.77
GT2: Public Service Delivery	17	0.91	0.06	0.88	0.93	0.95	103	0.66	0.26	0.49	0.73	0.87
GT3: Citizen engagement	17	0.72	0.20	0.61	0.73	0.86	103	0.47	0.29	0.24	0.39	0.74
GT4: GovTech Enablers	17	0.83	0.09	0.81	0.83	0.88	103	0.54	0.24	0.33	0.57	0.75

Turning to **PEFA scores**, the overall index ranges from 1 (weak) to 4 (strong). The mean value of the overall score across 110 countries is 2.53, with variation across sub-indices. Service delivery quality, fiscal information disclosure, and public investment management show lower average score. This highlights areas where developing countries have scope to improve fiscal risk reporting, transparency, and public investment management practices.

Table A.2: PEFA Index

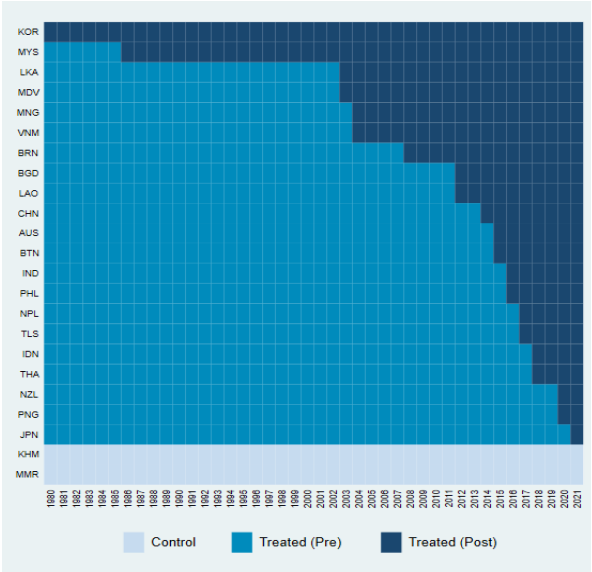
	N	Mean	Std dev	P25	P50	P75
PEFA: overall average	110	2.53	0.51	2.22	2.52	2.94
<u>Sub-index</u>						
PEFA: Expenditure Outturns (against budget)	110	2.65	0.93	2.00	2.92	3.50
PEFA: Revenue Outturns (against budget)	110	2.80	0.93	2.13	3.00	3.50
PEFA: Performance information for service delivery	65	1.94	0.80	1.50	1.50	2.50
PEFA: Public access to fiscal information	65	1.98	1.25	1	1	3
PEFA: Fiscal risk reporting	65	1.76	0.71	1	1.5	2.25
PEFA: Public investment management	64	1.78	0.67	1.5	1.5	2
PEFA: Procurement management	109	2.12	0.83	1.5	2	2.75
PEFA: Expenditure arrears control	110	2.15	0.98	1.33	2	3

C. The Timing of Government Digital Adoption

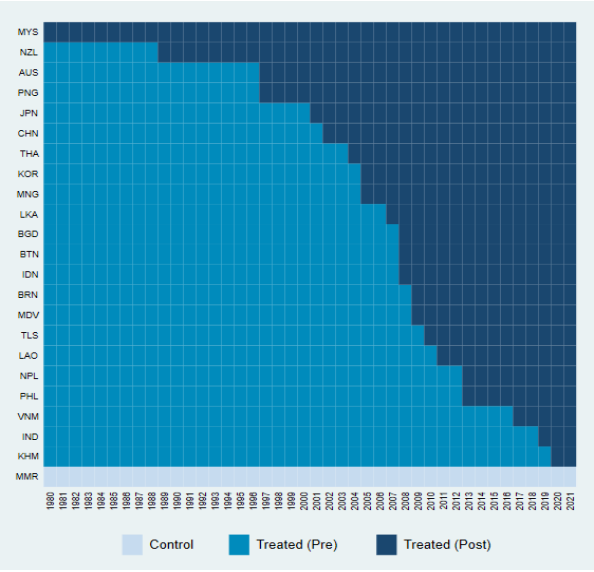
Digital technology has been rolled out and fully integrated into fiscal operations at a different time. The Appendix Figures A1-A5 illustrate the year of a country's GovTech adoption in four key areas across regions: (a) the establishment of a dedicated GovTech institution, (b) the launch of TSA IT system with full integration to FMIS, (c) launch of e-Procurement platform, and (d) the digitalization of PIMS.

Figure A.1. Year of GovTech Adoption in the Asian and Pacific Region

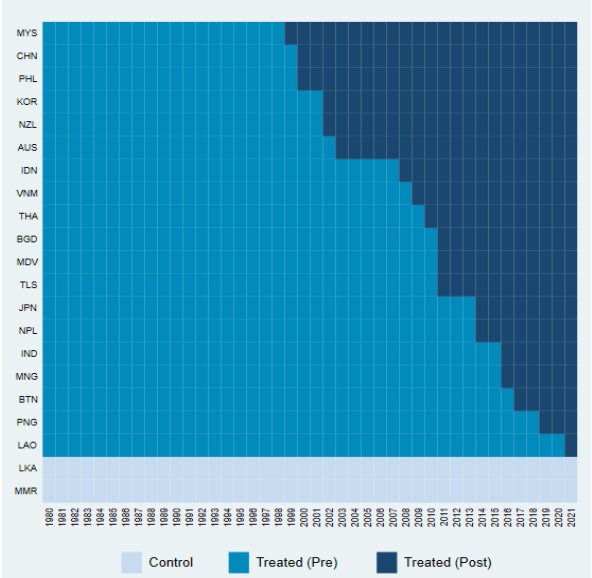
a. Establishment of a GovTech institution



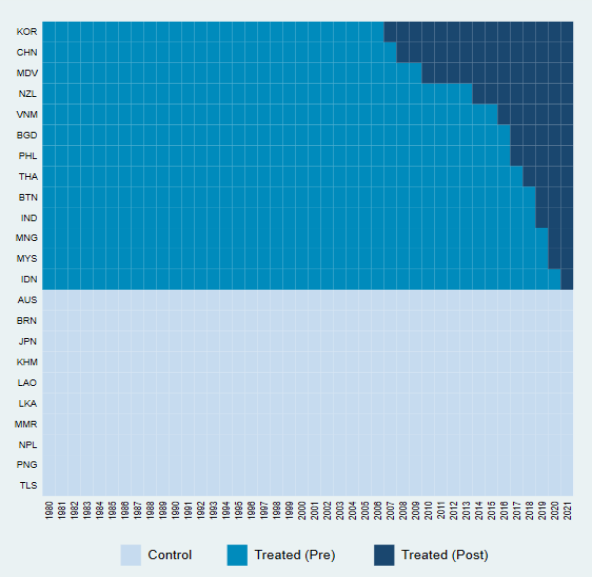
b. Launch of TSA IT System (linked with the FMIS)



c. Digitalized e-Procurement Portal



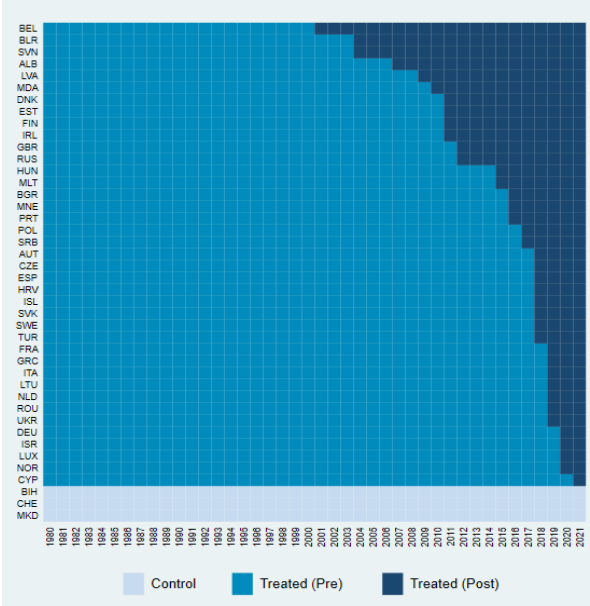
d. Digitalized PIMS



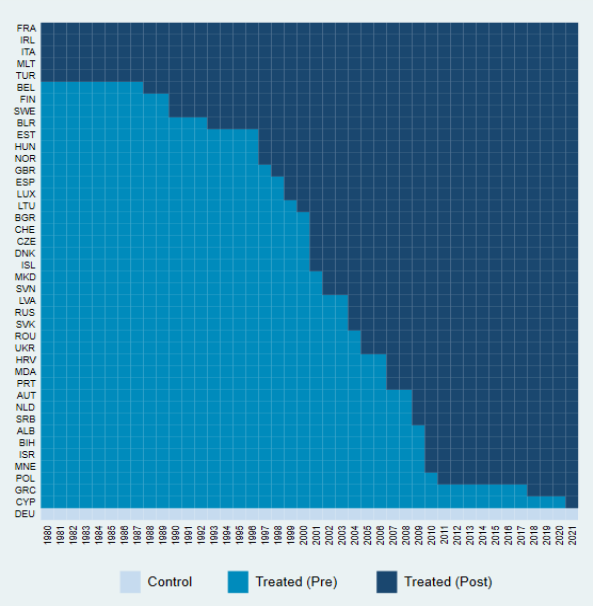
Source: GovTech Maturity Index, 2020 and 2022
Note: The dark blues indicate the period after the digitalization. The countries that are yet to digitalize respective government function are categorized as a control group. Country names are presented in ISO3 code.

Figure A.2. Year of GovTech Adoption in the European Region

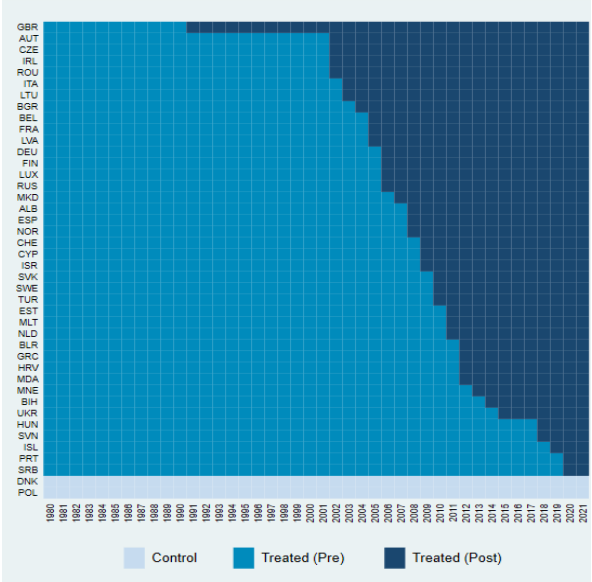
a. Establishment of a GovTech institution



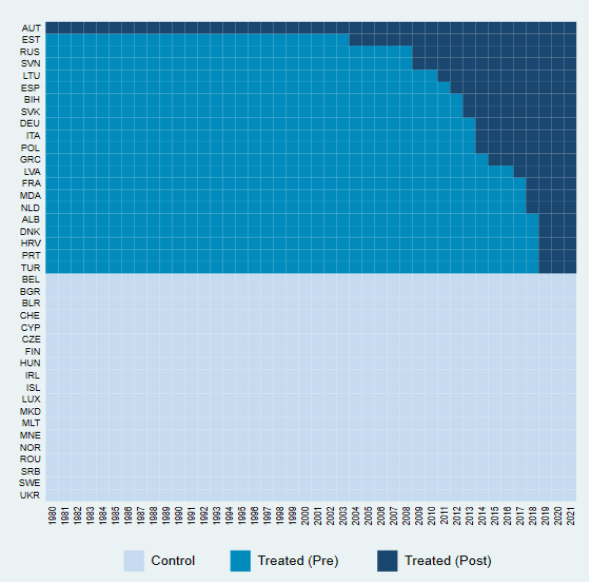
b. Launch of TSA IT System (linked with the FMIS)



c. Digitalized e-Procurement Portal



d. Digitalized PIMS

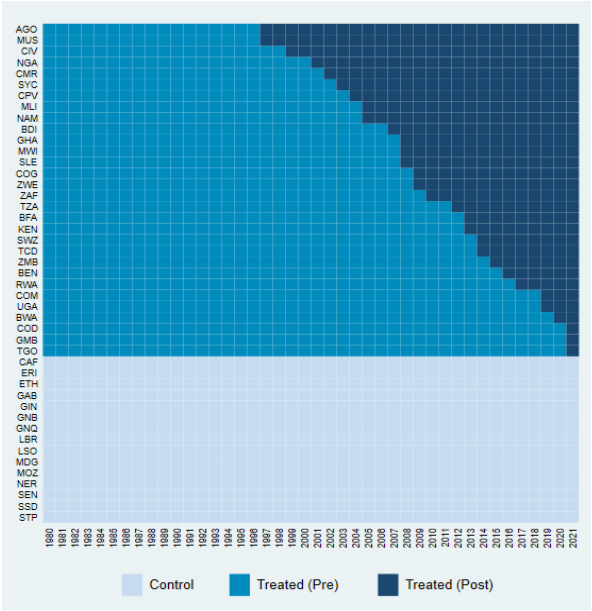


Source: GovTech Maturity Index, 2020 and 2022

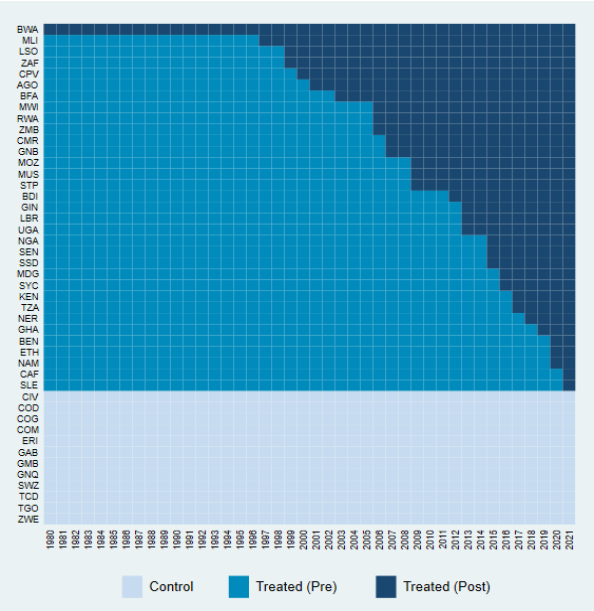
Note: The dark blues indicate the period after the digitalization. The countries that are yet to digitalize respective government function are categorized as a control group. Country names are presented in ISO3 code.

Figure A.3. Year of GovTech Adoption in the sub-Saharan African Region

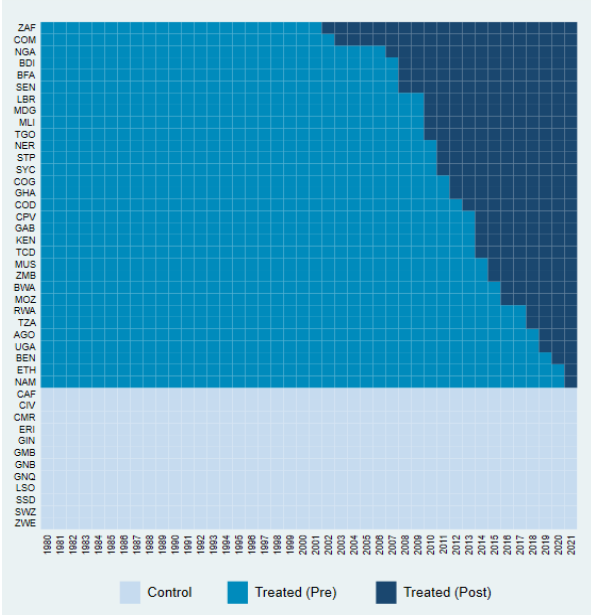
a. Establishment of a GovTech institution



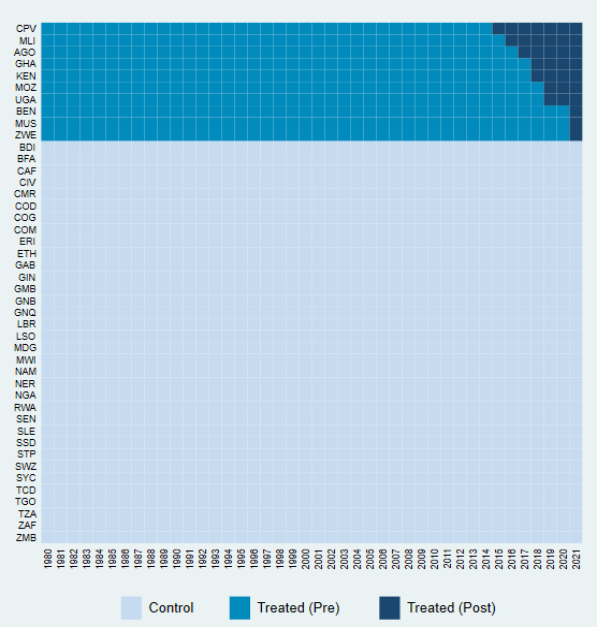
b. Launch of TSA IT System (linked with the FMIS)



c. Digitalized e-Procurement Portal



d. Digitalized PIMS

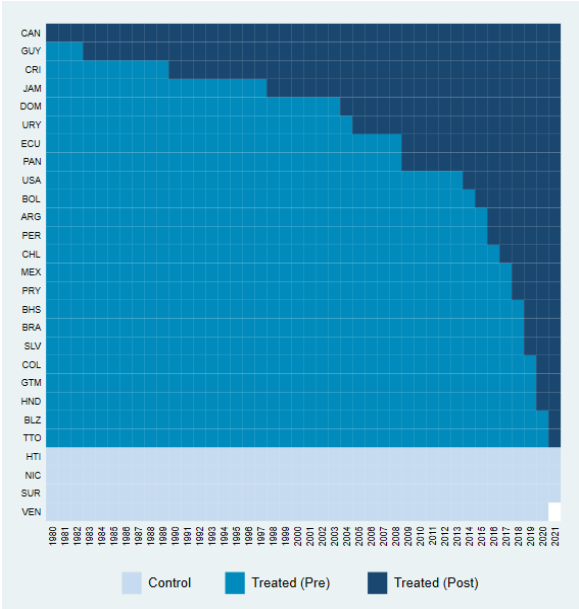


Source: GovTech Maturity Index, 2020 and 2022

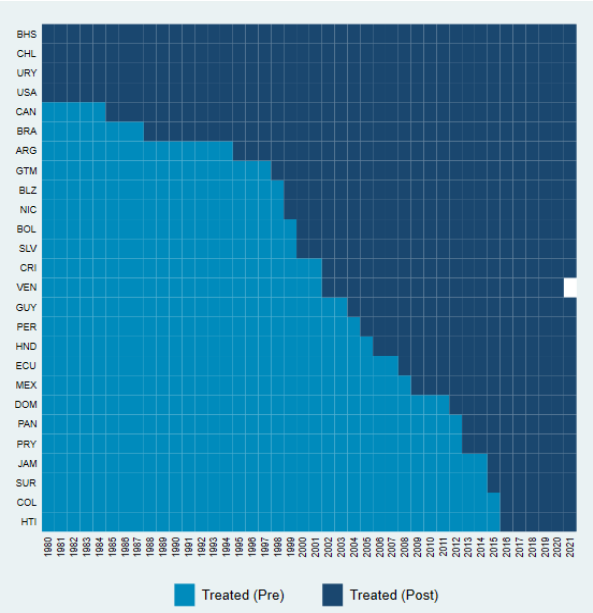
Note: The dark blues indicate the period after the digitalization. The countries that are yet to digitalize respective government function are categorized as a control group. Country names are presented in ISO3 code.

Figure A.4. Year of GovTech Adoption in the Latin America Region

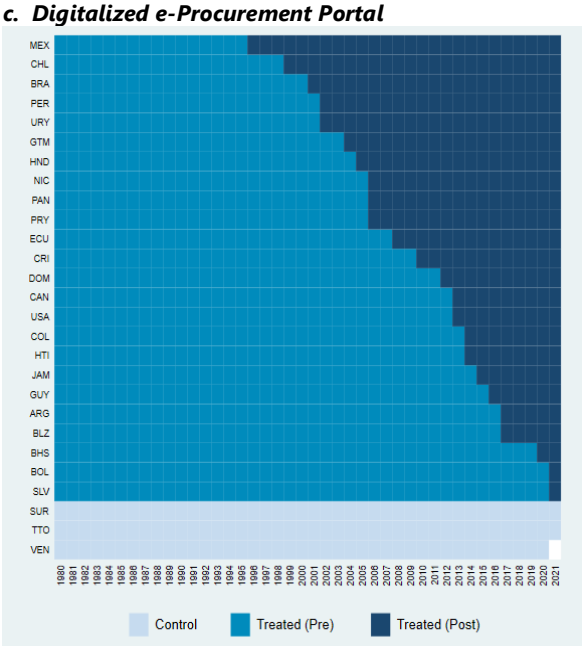
a. Establishment of a GovTech institution



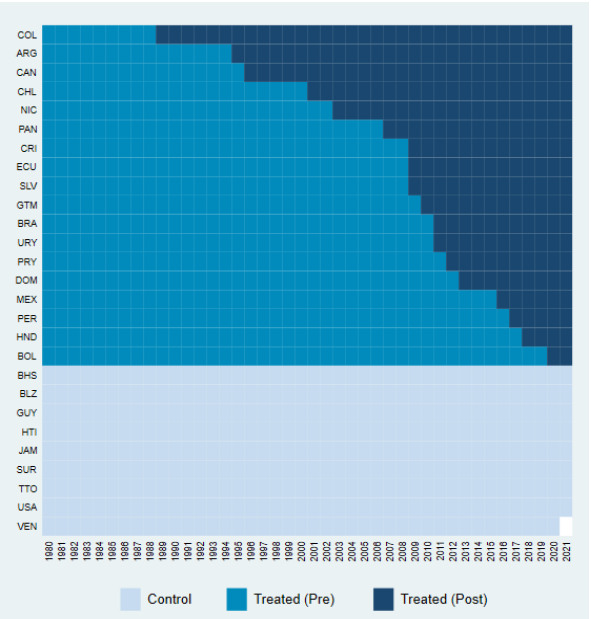
b. Launch of TSA IT System (linked with the FMIS)



c. Digitalized e-Procurement Portal



d. Digitalized PIMS

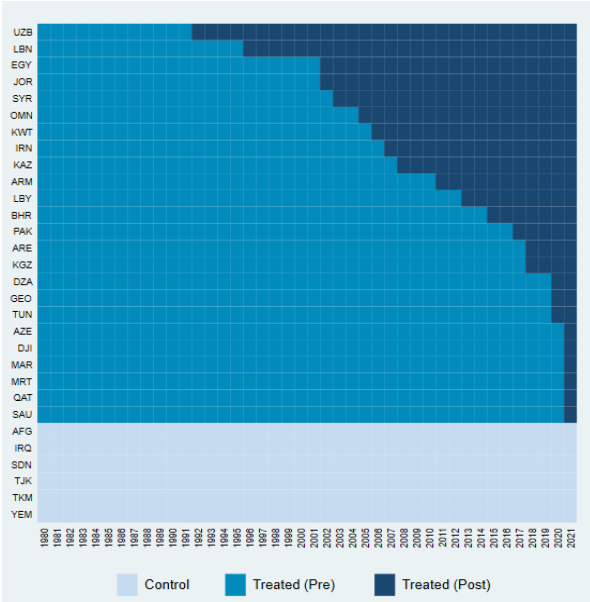


Source: GovTech Maturity Index, 2020 and 2022

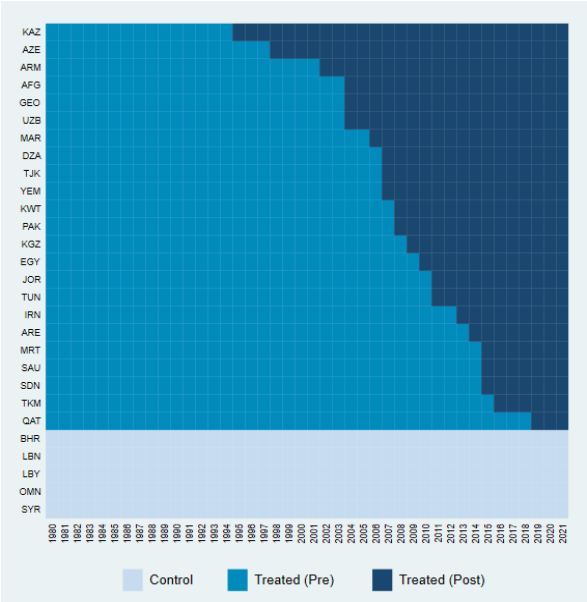
Note: The dark blues indicate the period after the digitalization. The countries that are yet to digitalize respective government function are categorized as a control group. Country names are presented in ISO3 code.

Figure A.5. Year of GovTech Adoption in the Middle East & Central Asia Region

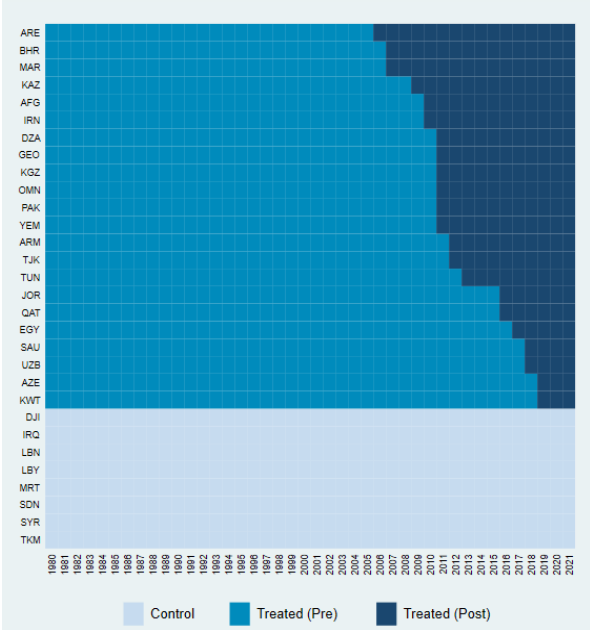
a. Establishment of a GovTech institution



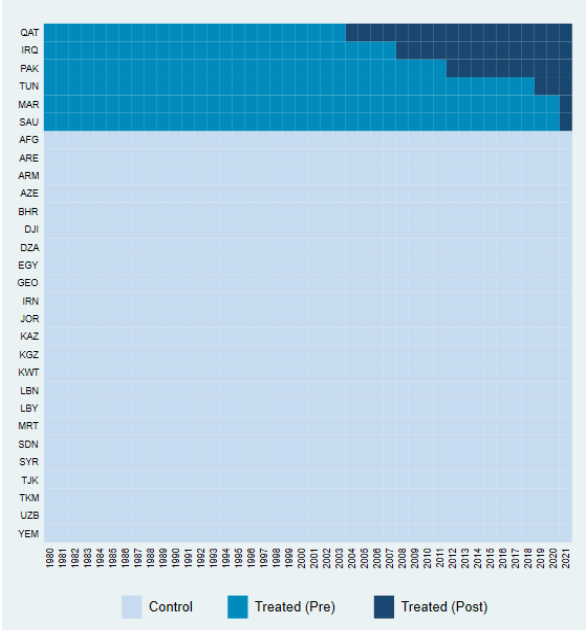
b. Launch of TSA IT System (linked with the FMIS)



c. Digitalized e-Procurement Portal



d. Digitalized PIMS



Source: GovTech Maturity Index, 2020 and 2022

Note: The dark blues indicate the period after the digitalization. The countries that are yet to digitalize respective government function are categorized as a control group. Country names are presented in ISO3 code.

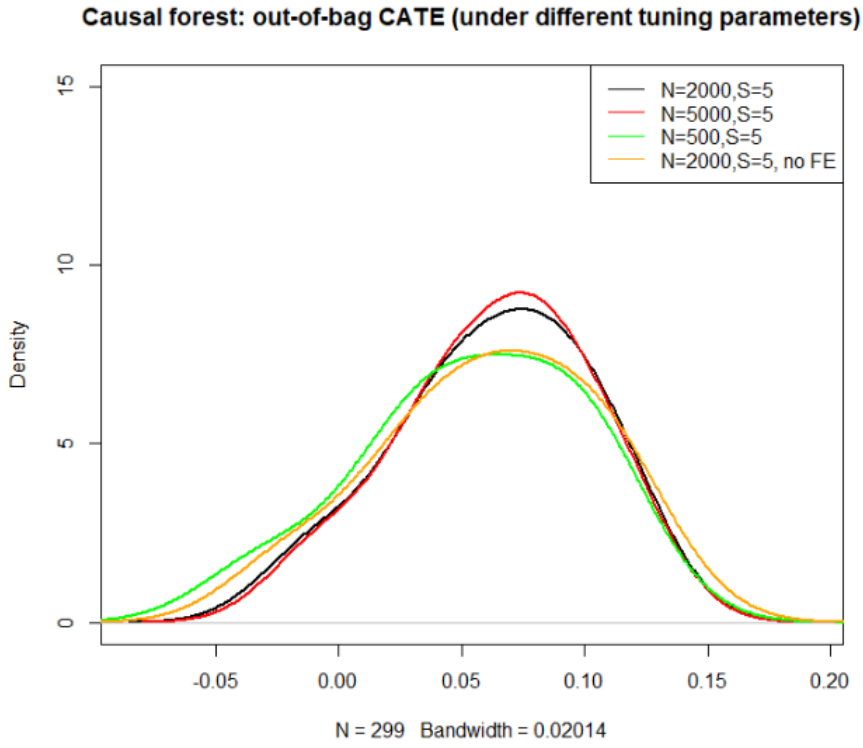
D. Causal Forest under an Alternative Specification and Parameter Tuning

The kernel density plot (Figure A.6) shows the distribution of the CATE under alternative model specifications and hyperparameter tuning values. We examine the sensitivity of the CATE to three tuning parameter settings with different number of trees (N) and the minimum node size of individual trees (S): (a) N=2,000 and S=5 (the default value), (b) N=5,000 and S=5, (c) N=500 and S=5, and (d) N=2,000 and S=5 without regional and year dummies.

As Figure A.6 shows, the performance of out-of-bag CATE prediction is similar when the tuning parameter changes from the default value. This indicates that the model performance is robust under the alternative empirical specifications when tuning parameters change from the default value.

In the main text, Figure 7 reports the CATE estimate using the default values when the forest cross-validate tuning parameter.

Figure A.6: Distribution of CATE under Alternative Specifications and Tuning Parameters



Note. The causal forest is estimated with log per capita GDP (level and square terms), the income share of agriculture, the control of corruption, GTMI enabler index, enhanced digital connectivity index, as well as regional and year dummies.

E. Causal Forest: Variable Importance Values

When the model specification changes, the variable importance values change as it does not relate to the ground truth but rather to the model explanation. Using the causal forest models under four alternative specifications (with different tuning values + with or without region and year fixed effects; as in Figure A.6, the stability of variable importance is also evaluated. Figure A.7 shows the range of variable importance estimates for three main explanatory variables in determining the social assistance coverage ratio (i.e., GovTech enablers, digital connectivity, and control of corruption). Both GovTech enabler and digital connectivity are consistently one of the two most important features in detecting treatment heterogeneity among all covariates. On average, both variables are frequently selected for splitting the trees (about 13 percent for GovTech enabler and 20 percent for digital connectivity) in the random forest regression.

Figure A.7: Variable Importance Estimates under Alternative Specifications and Tuning Parameters