Long-Run Growth Impact of E-Procurement: Evidence from Singapore

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Abstract

We examine the contribution of the e-procurement take-up to long-run growth and development. To this end, we exploit the introduction of large-scale e-procurement platform in the government administration in Singapore in 1998. Our approach is to construct the counterfactual scenario for long-run growth in the absence of e-procurement to estimate the long-run growth benefits of smart digital solutions in public services. By exploiting the parallel trends between Singapore and the rest of the world in pre-1998 period, we are able to match Singapore with a control sample of more than 100 countries for the period 1950-1997 to build a synthetic control group for the post-1998 period, and construct Singapore's counterfactual long-run growth path. Our results indicate large and pervasive growth gains from implementing e-procurement. Using a large set of covariates to address pre-treatment imbalance, we find that the counterfactual growth trajectory in the absence of e-procurement take-up is substantially worse off. The estimated growth effects of e-procurement increase over time and are robust across multiple specification checks. A battery of placebo checks and large-sample randomization inference confirm the significance of e-procurement policy for long-run growth, which does not seem to be driven by chance.

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1 Introduction

The notion that institutional framework that supports the rule of law, secure property rights and low transaction costs matters a great deal for the long-run growth and the wealth of nations can only seldom be disputed (North 1987, Knack and Keefer 1995, Hall and Jones 1999, Easterly and Levine 2003, Rodrik et. al. 2004, Roland 2004, Acemoglu et. al. 2001, 2002, 2005, Van Zanden et. al. 2012). Many scholars agree that sustained long-run growth and economic prosperity is almost impossible in an institutional environment with a weak rule of law (Méon and Sekkat 2005, Easterly et. al. 2006, Haggard and Tiede 2011, Campos et. al. 2012), low-quality administration of justice (Torstensson 1994, Goldsmith 1997, Posner 1998), high costs of enforcing contracts (Olson 1992, Barro 1996, Clague et. al. 1999, Rajan and Zingales 2001, Prados de la Escosura and Sanz Villaroya 2009) and ineffective government administration (Gelb et. al. 1991, Przeworski et. al. 1995, La Porta et. al. 1999, Dalamagas 2000, Rodrik 2000, Kraay and Kaufmann 2002, Rothstein and Teorell 2008, Fátas and Mihov 2013) Countries with low-cost contract enforcement and highly effective government administration are significantly more likely to implement policies that promote sustained long-run growth while those with high-cost contract enforcement generally fail to implement growth-enhancing policies, and are condemned to economic stagnation and underdevelopment (Scully 1988, North 1991, Alesina and Perotti 1994, Mauro 1995, Alesina et. al. 1996, Dawson 1998, Henisz 2000, De Haan et. al. 2006, Coatsworth 2008).

If the inadequate institutional environment is to blame for the failure to sustain high rates of economic growth, the question that remains less clear is which policies help pursue long-run growth and development. Not everyone agrees that institutional changes are the fundamental cause of long-run income gaps across countries. A large strand of literature suggests that large and persistent income differences across countries may be attributed to the adverse physical geography (Diamond 1997, Bloom and Sachs 1998, Gallup et. al. 1999, Sachs and Malaney 2002, Auer 2013, Cook 2014). Others believe that culture is the decisive factor in the determination of income differences (Landes 1998, Guiso et. al. 2006, Mokyr 2009, Tabellini 2010). In its form of preferences and behavioral patterns, it can hold long-lasting economic implications and may possibly act as a brake or filter in the process of long-run growth (Jones 2006).

The notion of persistent effects of institutional environment on long-run growth has been challenged. For instance, Glaeser et. al. (2004) argue that human capital accumulation is more a basic source of growth than is the institutional environment, and that poor countries often escape poverty trap through good policies, often pursued by dictators. By contrast, Acemoglu and Johnson (2005) challenge this particular claim and argue that property-rights institutions have a major influence on long-run growth while changes in contracting institutions appear to be less important. If the ignorance of good policies is one of the main impediments to sustained long-run growth, the question that remains is which policies can foster sustained long-run growth.

Some scholars believe that regulatory policies matter a great deal for economic growth. Djankov et. al. (2006) argue that countries with better regulations tend to grow faster, and show that improving from the worst quartile to the best implies about 2 percentage point increase in annual growth. In quantitative terms, 2 percentage points higher rate of growth implies that per capita income doubles three times faster, which highlights an deep importance of the regulatory policies and their institutional design for the long-run growth, which may be causal (Jalilian et. al. 2007). Dawson and Seater (2013) find that regulation has a statistically and economically significant negative effect on per capita output and total factor productivity. Drawing on the US federal regulation, they argue that regulatory changes may be responsible for the productivity slowdown in the 1970s. Furthermore Nicoletti and Scarpetta (2003) show that regulatory reforms that strengthen private corporate governance and competition boost productivity growth, and suggest that the lack of such regulatory reforms may explain the slow-productivity performance of some European countries. In addition, Alesina et. al. (2005) present sector-level evidence across many OECD countries confirming the beneficial effects of removing barriers to entry on investment rates. A substantial body of literature further argues that a heavier regulatory burden may induce informality (Loayza et. al. 2006, Galiani and Weinschelbaum 2012)

The conventional wisdom suggests that regulatory barriers are one of the major causes of large income differences (Parente and Prescott 1999). Productivity differences are primarily the result of country-specific policies, distortions and barriers to entry that impose constraints on the labor supply, and on the application of better firm-level technology. Many of these barriers protect the interests of groups vested in the current production process, discourage the adoption of better technology, and may possibly lead to slow economic growth (Rajan 2009, Spruk and Kovac 2018). On the other hand, legal institutions have a significant impact on the efficient use of technology and may either help or hurt economic growth (Williamson 1994, Levine 1998, Berkowitz et. al. 2003, Beck and Levine 2005, Arruñada and Garoupa 2005, Castro et. al. 2009, Chang 2011, Cooter and Schäfer 2012). In this respect, the question that remains unclear is whether removing policy-imposed distortions and barriers to entry can be identify and whether they improve long-run growth.

In this paper, we examine the effect of implementing e-procurement in the government administration on economic growth. To this end, we exploit the introduction of e-procurement take-up by Singapore in 1998 as a source of variation in long-run growth. In 1998, Singapore implemented a large-scale public e-procurement system as one of the first countries to move the public-sector procurement process online by developing an ambitious e-procurement portal. We estimate the long-run growth impact of implementing e-procurement by using synthetic control methodology (Abadie et. al. 2010, 2015), and construct a counterfactual growth scenario in the absence of e-procurement implementation. We deploy a dynamic Arellano-Bond specification into the standard synthetic control estimator to partially address the potential endogeneity of e-procurement policy change, and utilize a large battery of long-run growth covariates.

Drawing on a sample of more than 100 countries for the period 1950-2008, our comparative evidence indicates large and pervasive growth gains from introducing e-procurement. Prior to 1998, the long-run growth path of Singapore appears to be well-described by growth trends of countries at the parallel stages of development. After 1998, Singapore's long-run growth tends to break off its synthetic control group with little evidence on pre-existing trends. Numerous placebo checks and randomization inferences confirm the statistical and economic significance of the growth effects of e-procurement. Our results question the notion that countries cannot escape low-growth poverty trap even in the presence of growth-enhancing policies, and show that, when well managed and consistently enforced, such policies can produce persistent and substantial long-run growth benefits.

The rest of the paper is organized as follows. Section 2 reviews the policy background. Section 3 presents our identification strategy. Section 4 discusses the data and samples. Section 5 proceeds with results and robustness checks. Section 6 concludes.

2 Background

Singapore is a city state without local government and sub-central authorities and government procurement activities in Singapore are decentralized to individual government agencies, which must adhere to central procurement guidelines issued by the Ministry of Finance (Chia 2009). As such, the benefits of a "one-stop-electronic-shop" in public procurement could arguably enhance the efficiency of public purchasing and in turn enhance the economic growth of the country.

Public procurement regulation in Singapore has been shaped by diverse international agreements, especially the World Trade Organisation Agreement on Government Procurement 1994, the Agreement between New Zealand and Singapore on a Closer Economic Partnership, the Agreement between Japan and Singapore for a New Age Economic Partnership, EFTA-Singapore Free Trade Agreement and Singapore-Australia Free Trade Agreement and the US-Singapore Free Trade Agreement. The general act governing public procurement is the Government Procurement Act, Chapter 120, with four accompanying regulations: Government Procurement (Challenge Proceedings) Regulations, Government Procurement Regulations, Government Procurement Order and Government Procurement Act Notification 2002 (ADB/OECD 2006). Inspired by its international obligations, Singapore strived to enhance the transparency of its public procurement processes, with fairness, value for money and probity representing main policy goals (Harland et al. 2006).

In terms of e-government implementation, Singapore has been one of the most successful jurisdictions globally (Ke and Kee Wei 2004). It's e-government portal has been called "the most developed example of integrated service delivery in the world" (America's General Service Administration 2000), generating approximately 14.5 million USD savings yearly (Accenture Consulting 2001). This success has been attributed to Singapore's stable government with a long-

term commitment to ensure the benefits of technology are maximized (Ke and Kee Wei 2004). As a part of this e-government action plan and under the general Government Procurement Act, in 1998 Singapore implemented an e-procurement portal (Government Electronic Business Portal, GeBIZ) of a mandatory nature: in stages, all public procurement needed to become electronic. All the public procurement stages, from supplier registration to tendering and the payment of invoices, were mandated to become electronic. GeBIZ portal acts as a one-stop-shop for government and business interaction. Detailed central procurement guidelines, albeit without the force of law, have been published by the Ministry of Finance on the use and functioning of GeBIZ. Due to the support from the Ministry of Finance and well-defined objectives, it has been successful and well-managed since its inception. As one of the largest government e-commerce initiatives, GeBIZ was meant to "foster a more transparent and fair trading environment that would result in better value for money for the public service," (Centre for Public Impact 2016) and this article seeks to test this hypothesis. The system has been implemented in phases: in 1998 the e-government procurement has been defined, two years later buyer buy-in has been implemented, followed by supplier buy-in in the year 2002 and extended services in 2004, with the final transition to collaborative procurement in 2007 (Chia 2009).

All these milestones can potentially exhibit positive growth-effects, which are tested in the following sections, albeit the official launch of the GeBIZ portal has been dated as of the year 2000 (KPMG 2018). The public impact of GeBIZ implementation has been substantial: while at the end of the year 2005 there were more than 9,000 users in the public sector from 120 government agencies, further growth has been reported in the year 2008. GeBIZ in 2008 accounted for 10,000 buyers, 144 participating agencies, 79,000 quotations worth approximately 600 million EUR and 42,000 suppliers participated in bids (Centre for Public Impact 2016). According to this activity, we examine if this transition to e-tendering altered the growth pattern by using synthetic control estimator. As we observe a growing per capita and real/synthetic gap over time, we interpret this as evidence that future improvements of the system in years 2006 and 2007 are influencing the size of the effect of e-procurement on economic growth.

3 Identification Strategy

Our goal is to examine the contribution of e-procurement take-up to economic growth consistently. To this end, we estimate the effect of e-procurement implementation on growth using synthetic control estimator (Abadie and Gardeazabal 2003, Abadie et. al. 2010, 2015, Cavallo et. al. 2010, Billmeier and Nannicini 2013, Acemoglu et. al. 2016, Gobillon and Magnac 2016, Klößner et. al. 2018) to construct a counterfactual growth trajectory in the absence of e-procurement take-up. Our key identifying assumption invokes parallel growth trends to serve as a reliable source of counterfactual for what the growth would have been in Singapore as a treated country in the absence of the e-procurement reform.

More formally, we observe C+1 countries where Singapore is denoted as $c = 1$ country being exposed to the e-procurement take-up while C-1 represents the control group of countries that serves as a donor pool to construct Singapore's counterfactual growth trajectory. Let $y_{c,t}^{N}$ denote the per capita output in the absence of e-procurement take-up. Suppose that T_0 represents the number of years before the e-procurement policy intervention where $1 \leq T_0 < T$. Let $y_{c,t}^{I}$ denote the per capita output of Singapore in the full post-intervention period starting at $T_0 + 1$. Our second identifying assumption is that the e-procurement take-up has no effect on the per capita output in the period before the implementation. This implies that we have $y_{c,t}^{N} = y_{c,t}^{I}$ for all $t \in \{1,...,T_0\}$ and $c \in \{1,2,...C\}$.

The per capita output in c-th country at time t is given by:

$$y_{c,t} = y_{c,t}^{N} + \lambda_{it} \cdot 1[i = 1, t > T_0]$$

where $1[c = 1, t > T_0]$ is an Iversonian dichotomous function indicating whether i-th country is after the period T_0 is exposed to the e-procurement take-up. The full impact of e-procurement implementation on growth is then given by:

$$\lambda_{1t} = y_{1t}^{I} - y_{1t}^{N} = y_{1t} - y_{1t}^{N}$$

But since y_{1t}^{I} is unobserved to the econometrician, we estimate the counterfactual growth trajectory y_{1t}^{N} to obtain a consistent representation of λ_{1t}. Consider a $C \times 1$ vector of weights $\mathbf{W} = (w_2,...,w_{C+1})$ such that $w_j \geq 0$ for $c = 2,...,C+1$ with an additive structure, $w_2 + ... + w_{C+1} = 1$. Each particular value of the vector represents a country-level weight share of the total for Singapore's synthetic control group. Following Abadie et. al. (2010), the synthetic control group is simply defined as a weighted average of outcome-level and covariate-level pre-treatment growth characteristics. Hence, the reweighted per capita output that captures the counterfactual growth trajectory is given by:

$$\sum_{c=2}^{C+1} w_c \cdot y_{c,t} = \boldsymbol{\eta}_t \sum_{c=2}^{C+1} w_c \mathbf{Z}_c + \pi_t \sum_{c=2}^{C+1} w_c \mathbf{M}_c + \sum_{c=2}^{C+1} w_c \varepsilon_{c,t}$$

where $\mathbf{W} = (w_2,...,w_{C+1})$ is the approximate characterization of the Singapore's growth trajectory without the e-procurement take-up introduced in the period $t > T_0$, $\mathbf{M}_c$ is the vector of

unobserved factor loadings, $\mathbf{Z}_c$ is the vector of covariates. Hence, the effect of the ban is characterized as follows:

$$\tilde{\lambda}_t = y_{1t} - \sum_{c=2}^{C+1} w_c^* \cdot y_{c,t}$$

If the pre-treatment characteristics and parallel trends of the synthetic control group are sufficiently well matched with Singapore in pre-T_0 period, the underlying fit between Singapore and its synthetic control group captures the parallel growth trends before the e-procurement take-up. This allows us to construct a synthetic control group of the following form:

$$\sum_{c=2}^{C+1} w_c \mathbf{Z}_c = \mathbf{Z}_1 \qquad \sum_{c=2}^{C+1} w_c \mathbf{M}_c = \mathbf{M}_1$$

such that it yields an unbiased estimator of y_{1t}^N. Since $\mathbf{M}_1,...,\mathbf{M}_{C+1}$ is not observed to the econometrician, Abadie et. al. (2010) show that under standard conditions, the latent component model for the outcome can fit $\mathbf{Z}_1$ and the subset of pre-intervention growth outcomes as long as it fits $\mathbf{Z}_1$ and $\mathbf{M}_1$. A simple vector-autoregressive model can clearly provide a reasonably unbiased estimate of the effect of the e-procurement take-up by allowing for time-varying coefficients even if $T_0 = 1$ but since our setup invokes a reasonably large pre-intervention period, a synthetic match between Singapore and the control sample of countries on $\mathbf{Z}$ can provide a plausible representation of $\tilde{\lambda}_t$.

Our synthetic control implementation procedure is similar to Abadie and Gardeazabal (2003), and Abadie et. al. (2010). Since each value of $\mathbf{W}$ represents a weighted covariate-level average of the control group without the exposure to the e-procurement take-up, let $\mathbf{X}$ denote the vector of covariates. Such a weighted average is a convex combination of unexposed countries inside the convex hull, which ensures that $w_2 + ... + w_{C+1} = 1$. The choice of weights can be somewhat arbitrary, and may come at the expense of extrapolation. We partially address the arbitrariness of the weights by performing a nested optimization route to find the best synthetic control match for Singapore. More specifically, we build a vector $\mathbf{W}^*$ to minimize the per capita output distance between the Singapore and control group countries, denoted by $\|\mathbf{X_1} - \mathbf{X_0}\mathbf{W}\|$ subject to $w_2 > 0$ and $w_2 + ... + w_{J+1} = 1$. An obvious choice for distance minimization would be to compare the outcome values for the full pre-intervention period, namely $y_0^{\mathbf{K}_1},...,y_0^{\mathbf{K}_M}$ against $y_1^{\mathbf{K}_1} = y_{i1},...,y_i^{\mathbf{K}_{T_0}} = y_{iT_0}$. To address the discrepancy between $\mathbf{X}_1$ and $\mathbf{X_0}\mathbf{W}$, we use the positive and symmetric semi-definite matrix as a linear combination of pre-intervention outcomes as recommended by Abadie et. al. (2010):

$$\left\|\mathbf{X}_1 - \mathbf{X}_0\mathbf{W}\right\|_V = \sqrt{\left(\mathbf{X}_1 - \mathbf{X}_0\mathbf{W}\right)' \mathbf{V}\left(\mathbf{X}_1 - \mathbf{X}_0\mathbf{W}\right)}$$

where $\mathbf{V}$ is the symmetric semi-definite positive matrix. Since the relationship between public health outcomes and the full set of covariates in our setup is unlikely to exhibit non-linearity, the set of penalty terms of expanding covariates and outcome distance is low. We further address the discrepancy in the covariate composition by restricting the control group to the countries that are similar to Singapore in terms of $\mathbf{X}_1$ values. Such cross-validation procedure is based on minimizing the mean squared error of the synthetic control estimator which ensures that the synthetic counterfactual approximates the long-run growth path of Singapore over time in the full pre-intervention period before the e-procurement take-up.

4 Data and Samples

Our dependent variable is per capita GDP denoted in 1990 Geary-Khamis dollars using multiple benchmark method (Inklaar et. al. 2018). Our list of long-run growth covariates consist of (i) pre-procurement reform GDP per capita dynamics, (ii) physical geography covariates, (iii) demographic covariates, (iv) culture and human capital covariates, (v) macroeconomic covariates, (vi) legal history covariates, and (vii) institutional quality covariates.

We proxy pre-reform GDP per capita dynamics by using four lags of the pre-1998 GDP per capita which embeds dynamic panel-level regression into the synthetic control setup. The set of physical geography covariates (Nunn and Puga 2012) comprises latitude, longitude, soil quality, fraction of desert area, fraction of tropical area, mean distance to coast, fraction of area within 100 km of coastline, terrain ruggedness and size of the land mass area. The demographic covariates comprise population size, population density per square km, and population growth rate (Maddison 2007, Census Bureau 2016). Since these variables are closely related to our dependent variable and might violate the treatment effect of e-procurement take-up, we average each variable over 1950-1997 period to partially address standard confounding issues. The culture and human capital covariates comprise the first principal component of Hofstede cultural dimensions (Hofstede 1998), level of IQ (Lynn and Meisenberg 2010), and a composite index of social capital (Spruk and Keseljević 2016). The macroeconomic covariate consists of export share of GDP as a rough but imperfect proxy for trade openness (Feenstra et. al. 2015), while the data on the legal origins from La Porta et. al. (1998) is used to capture the contribution of distinctive legal history to long-run growth.

The set of institutional covariates consists of de jure and de facto judicial independence (Voigt et. al. 2015), aggregate governance indicators of corruption, rule of law, political stability, regulatory quality, government effectiveness, and voice and accountability, (Kaufmann et. al. 2011), the level of democracy proxied by Polity2 score (Marshall et. al. 2016), indicators of proportional versus majoritarian parliamentary representation (Persson and Tabellini 2003), and level of economic freedom (De Haan and Sturm 2000, Miller et. al. 2018). Notice that we only include the institutional covariates in the years preceding the e-procurement take-up to avoid the treatment effect of policy reform being contaminated by confounding bias. Our sample

consists of 105 countries[3] for the period 1950-2016. Table 1 reports the covariates means between Singapore and the rest of the world.

Table 1: Covariate balance between treatment and control samples

	Singapore	Rest of the World
Panel A: Pre-1998 GDP Per Capita Dynamics		
log GDP per capita$_{t-1}$	9.28	8.79
log GDP per capita$_{t-2}$	9.30	8.79
log GDP per capita$_{t-3}$	9.28	8.79
log GDP per capita$_{t-4}$	9.31	8.79
log gdp per capita in 1950	7.79	7.90
log gdp per capita in 1960	7.76	8.18
log gdp per capita in 1970	8.42	8.56
log gdp per capita in 1980	9.13	8.84
log gdp per capita in 1990	9.64	8.93
log gdp per capita in 1997	10.08	9.05
Panel B: Physical Geography Covariates		
Latitude	1.36	23.76
Longitude	103.82	12.73
Soil Quality	3.48	43.20
Desert area	0	1.81
Tropical area	100	27.16
Distance to coast	0.003	0.27
Fraction of area within 100km of coastline	100	44.00
Terrain ruggedness	0.016	1.40
Log land area size	6.53	12.13
Panel C: Demographic Covariates		
Population size (averaged 1950-1997)	7.89	9.10
Population growth (averaged 1950-1997)	2.64	1.54
Population density (averaged 1950-1997)	4342.13	124.95
Panel D: Culture and human capital covariates		
Culture (first principal component)	0.34	-0.060
IQ	108	89.55
Social capital	-1.20	0.17
Panel E: Macroeconomic covariates		
Export share of GDP	1.52	0.21
Panel F: Legal history covariates		
British common law	1	0.23
French civil law	0	0.54
German civil law	0	0.15
Scandinavian civil law	0	0.01
Panel G: Institutional covariates		

[3] Albania, Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Cameroon, Canada, Cape Verde, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Ghana, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Jordan, Kosovo, Lebanon, Luxembourg, Macedonia, Madagascar, Malaysia, Malta, Mauritius, Mexico, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, New Zealand, Nicaragua, Nigeria, Norway, Oman, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Serbia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Syria, Thailand, The Netherlands, Trinidad and Tobago, Tunisia, Turkey, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zambia, Zimbabwe

De jure judicial independence	0.54	0.65
De facto judicial independence	0.93	0.59
Control of corruption in 1996	2.16	0.23
Government effectiveness in 1996	2.10	0.29
Political stability in 1996	1.06	0.13
Quality of regulation in 1996	2.24	0.30
Voice and accountability in 1996	0.20	0.25
Rule of law in 1996	1.27	0.21
Polity2 score (averaged 1950-1997)	-2	4.66
Majoritarian representation system	1	0.22
Proportional representation system	0	0.31
Federalism	0	0.20
Economic freedom in 1996	87.30	59.72
Economic freedom in 1997	87.00	60.31

5 Results

5.1 Baseline estimates

Our results indicate strong and beneficial growth effects of introducing e-procurement that appear to persist over time. Table 1 reports the covariates means of real Singapore and its synthetic counterpart prior to the year of e-procurement policy reform. Even though the table does not contain any notion of statistically significant differences between real Singapore and its synthetic control group, the evidence indicates strongly similar mean values of covariates prior to the introduction of reform. Panel A reports pre-1998 GDP per capita covariates. Notice that our identification strategy replicates pre-procurement reform GDP per capita dynamics almost exactly. The four lags of the lagged GDP per capita variables closely approximate Singapore's long-run growth trajectory. In a similar vein, the synthetic Singapore matches its real counterpart surprisingly well in terms of the level of per capita GDP in certain benchmark years prior to the introduction of reform with little discrepancy in covariate means.

Panel B presents the covariate means between Singapore and its synthetic peer. The synthetic Singapore appears to be reasonably similar to the true Singapore in terms of plausibly exogenous physical geographic characteristics. A synthetic Singapore has a reasonably similar coastline characteristics, a similar longitude, and is about the same size as its real counterpart. Panel C reports the similarity in demographic characteristics where the same degree of similarity is prevalent. We are able to match real Singapore with its synthetic control group reasonably well since the latter has about the same population size, population growth and density as the real Singapore prior to the 1998 e-procurement policy reform. In terms of cultural and social capital characteristics. Matching on legal history and institutional covariates implies that the set of countries used to construct a synthetic control group comes from common-law tradition with some influence of German civil law background. In addition, the synthetic Singapore exhibits a strong similarity with its real counterpart in terms of the level of de jure and de facto judicial independence, level of democracy, quality of governance, and economic freedom.

Table 1: Covariate Means

	Real Singapore	Synthetic Singapore
Panel A: Pre-1998 GDP Per Capita Dynamics		
log GDP per capita$_{t-1}$	8.62	8.62
log GDP per capita$_{t-2}$	8.60	8.59
log GDP per capita$_{t-3}$	8.57	8.57
log GDP per capita$_{t-4}$	8.54	8.54
log gdp per capita in 1950	7.79	7.51
log gdp per capita in 1960	7.76	7.83
log gdp per capita in 1970	8.42	8.38
log gdp per capita in 1980	9.13	9.10
log gdp per capita in 1990	9.64	9.60
log gdp per capita in 1997	10.08	9.96
Panel B: Physical Geography Covariates		
Latitude	1.36	33.23
Longitude	103.82	71.83
Soil Quality	3.48	83.49
Desert area	0	0
Tropical area	100	0
Distance to coast	0.003	0.022
Fraction of area within 100km of coastline	100	97.22
Terrain ruggedness	0.016	1.95
Log land area size	6.53	7.91
Panel C: Demographic Covariates		
Population size (averaged 1950-1997)	7.66	7.72
Population growth (averaged 1950-1997)	2.86	1.36
Population density (averaged 1950-1997)	8.04	6.72
Panel D: Culture and human capital covariates		
Culture (first principal component)	0.34	-0.26
IQ	108	102
Social capital	-1.20	1.13
Panel E: Macroeconomic covariates		
Export share of GDP	1.46	0.43
Panel F: Legal history covariates		
British common law	1	0.74
French civil law	0	0
German civil law	0	0.25
Scandinavian civil law	0	0
Panel G: Institutional covariates		
De jure judicial independence	0.54	0.79
De facto judicial independence	0.93	0.81
Control of corruption in 1996	2.16	0.66
Government effectiveness in 1996	2.10	0.86
Political stability in 1996	1.06	0.89
Quality of regulation in 1996	2.24	1.01
Voice and accountability in 1996	0.20	0.78
Polity2 score (averaged 1950-1997)	-1.5	-0.55
Majoritarian representation system	1	0.27
Proportional representation system	0	0.53
Federalism	0	0.29
Economic freedom in 1996	87.3	69.2
Economic freedom in 1997	87	71.5

Figure 1 represents the baseline impact of e-procurement take-up on the economic growth. Panel (a) exhibits per capita GDP trends between Singapore and the rest of the world. Notice that Singapore's per capita GDP has moved up to the top percentiles of the world distribution at an accelerated pace starting around the year of the reform compared to the rest of the world. Panel (b) presents the synthetic control estimated impact of e-procurement take-up on the level of per capita GDP. The solid vertical line indicates the de facto year of e-procurement announcement whereas the dashed vertical line represents the de jure year of e-procurement policy change. For the sake of consistency, we use the year 1998 as the date of the policy change to evaluate the long-run growth impact of e-procurement. The evidence suggests a marked and strong impact of introducing e-procurement on economic growth. In the post-1998 period, the level of per capita GDP of real Singapore is consistently higher than the corresponding level of the synthetic control group. Our evidence suggests that the growth impact of the reform is strong since the gap between the real Singapore and its synthetic control group tends to widen over time in favor of the former.

In quantitative terms, our synthetic control estimates imply that the introduction of e-procurement take-up in 1998 is associated with pervasively higher level of per capita GDP. By 2016, per capita GDP of real Singapore is 103 percent higher than that of the synthetic control group. The growth benefits of e-procurement seem to be immediate with no sign or reversal given the per capita GDP trajectory in the control group. Pre-1998 discrepancy between Singapore and its synthetic control group is very low given that our pre-treatment period comprises 47 years until the timing of de jure policy change. The root mean square prediction error in the pre-1998 period is 0.092 or about 9% of the error margin, which appears to be reasonably and does not suggest that the underlying estimate would be plagued by the poor pre-treatment fit or poor covariate balance between Singapore and its control group. Figure presents the composition of synthetic control group. The set of countries that best match real Singapore on the battery of pre-1998 growth and development covariates at the parallel stage of development consists of Malta (45%), Hong Kong (27%), South Korea (25%), and Nepal (1%), respectively.

Figure 1: Synthetic Control Estimated Long-Run Growth Impact of E-Procurement

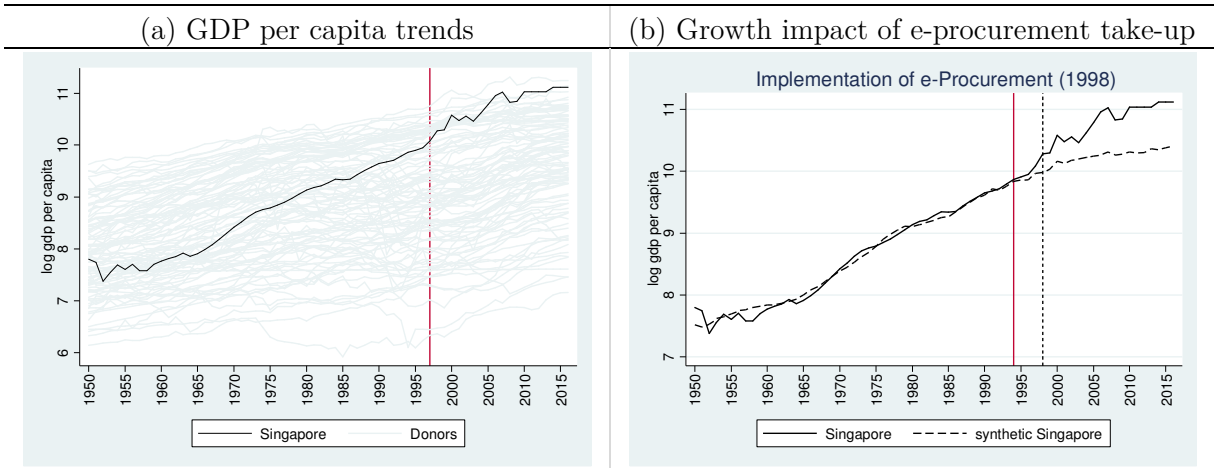
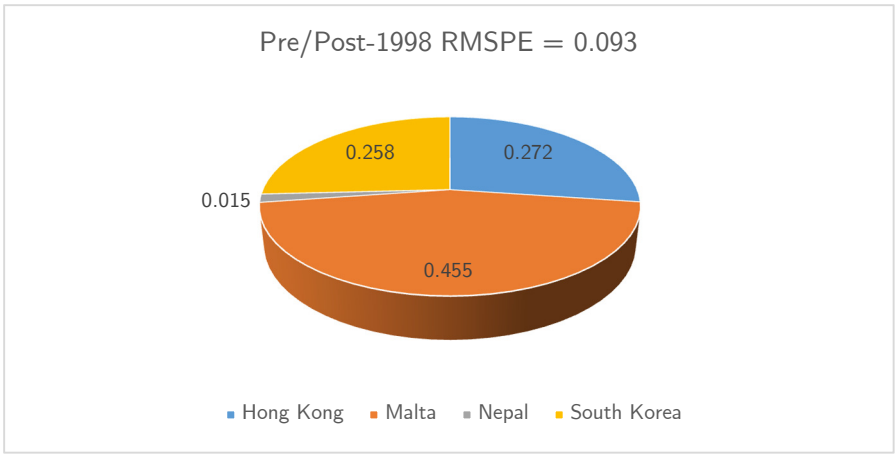


Figure 2: Composition of the Synthetic Control Group


Pre/Post-1998 RMSPE = 0.093
0.258
0.272
0.015
0.455
Hong Kong
Malta
Nepal
South Korea

5.2 Inference about the growth effect of e-procurement

We evaluate the significance of our baseline estimates by asking whether our results are driven by chance and may reflect the of factors other than e-procurement take-up. If our results are driven by chance, noise and may indicate factors other than e-procurement policy reform, one may think of whether the baseline estimated effects of the similar size and direction were obtained if we had randomly selected a country different from Singapore to study the growth impact of e-procurement. Such questions that may cast doubt on our results can be answered by using placebo tests. Following Abadie and Gardeazabal (2003), Bertrand et. al. (2004), and Abadie et. al. (2010, 2015), we run an extensive series of placebo studies by applying synthetic control estimator to the countries that did not implement a large-scale e-procurement take-up at the government level during the same sample period. If the placebo runs create gaps that are similar to Singapore in terms of magnitude and direction, then our analysis does not seem to provide significant evidence on the positive and substantial growth impact of e-procurement take-up. On the other hand, if the gap estimated for Singapore is unusually large compared to the gaps in the control group without e-procurement take-up, then we interpret the analysis as a source of evidence on the significant growth impact of procurement reform.

We assess the statistical significance of our estimates by consecutively applying the synthetic control estimate to examine the impact of the e-procurement take-up to all countries in the donor pool that did not undertake it. This implies that each iteration effectively moves Singapore to the donor and treat other countries as if they implemented large-scale e-procurement in 1998 instead of Singapore. Computing the estimated effect in each placebo run yields the distribution of per capita GDP gaps for the countries where the e-procurement has not been implemented in 1998. Suppose that the growth effect of e-procurement for the full post-treatment period is $\hat{\gamma}_{1t}$, and that the distribution of in-space effects from placebo runs is $\hat{\gamma}_{1t}^{Placebo} = \left\{ \hat{\gamma}_{jt} : j \neq 1 \right\}$. We compute the two-tailed p-valuen for the effect of e-procurement take-up as follows:

$$\text{p} - \text{value} = \Pr\left(\left| \hat{\gamma}_{1t}^{Placebo} \right| \geq \left| \hat{\gamma}_{1t} \right| \right) = \frac{\sum_{j \neq 1} 1 \cdot \left| \hat{\gamma}_{jt} \right| \geq \left| \hat{\gamma}_{1t} \right|}{J}$$

Notice that when the e-procurement take-up is randomly distributed across the sample, the placebo distributions provide a classical randomization inference. But since the e-procurement take-up is possibly not randomly distribted, may be anticipated, and may not fully satisfy the strict exogeneity assumption, we interpret the obtained p-values as the proportion of countries that have an estimated effects of the e-procurement take-up in the same year at least as large as the growth effect in Singapore. We further tackle the effects of e-procurement take-up by using the ratio of post- and pre-reform RMSPE to compare the effect in Singapore with the corresponding in-space placebo distribution for all untreated countries. Since placebo effects may be relatively large if the treated and control countries are not well matched by the set of

covariates in the pre-treatment period, we adjust the unrestricted set of placebo coefficients for the quality of pre-reform match in two steps. In the first step, we restrict the set of effects to include only those that match well. This implies that the large multiples of placebo effects relative to the one obtained for Singapore are removed from the in-space distribution (Abadie et. al. 2010). In the second step, the placebo effects are divided by the pre-reform match quality parameter to obtain the distribution of pseudo t-statistics, compute the relevant p-values, and conduct the statistical inference on the effects of e-procurement take-up.

Figure 3 presents the distribution of per capita GDP gaps from placebo runs. The gray line represents the difference in log per capita GDP between the quasi-treated country and its synthetic version while the black line denotes the estimated gap for Singapore. As indicated in panel (a), the estimated gap for Singapore appears to be large compared to the distribution of the gaps for the quasi-treated countries that did not undertake the e-procurement take-up. The discrepancy between real Singapore and its synthetic counterpart is very low and almost non-existent across the full range of pre-treatment years. The pre-reform mean sqaured prediction error in Singapore is 0.09 which suggest that the synthetic control method provides a reasonably good for per capita GDP prior to the e-procurement take-up in 1998. Per capita GDP trajectory cannot be well reproduced for some countries. Country with the worst pre-1998 fit is Mozambique with an MSPE of 0.53 followed by Iraq, Oman and Lebanon. If the synthetic Singapore had a poor fit of per capita GDP in the years preceding the e-procurement take-up, much of the post-1998 difference in per capita GDP would be attributed to an artifically created lack of fit rather than to the e-procurement reform. To tackle the rarity of estimating a large post-1998 gap, we follow Abadie et. al. (2010), and lower the prediction error cutoff down to the most demanding levels. In panel (b), we exclude countries with a pre-1998 MSPE of more than 20 times the MSPE of Singapore, which removes country-level observations for which synthetic control estimates provide a poor pre-intervention fit. The estimated gap for Singapore appears to be unusually large compared to the quasi-treated countries. In panel (c), we lower the cutoff the five-fold multiple of MSPE obtained for Singapore, which further reduces the quasi-treated country-level sample to those that match better with Singapore. The estimated gap for Singapore continues to display its unusual post-treatment trend compared to the donor states. In panel (d), we exclude countries with pre-1998 MSPE multiple of two compared to Singapore, and thus focus only on those that can display the same fit as Singapore in the period 1950-1997. The positive effect in Singapore is among the highest of all.

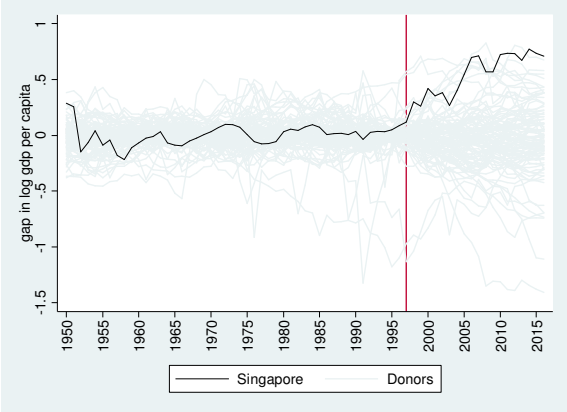
Figure 4 further evaluates the per capita GDP gap in Singapore relative to the gaps in quasi-treated countries from placebo checks, and examines the distribution of post/pre-procurement reform MSPE. This is how we can partially abstain from an arbitrary choice of cutoff to eliminate poorly-fit placebos. The ratio for Singapore is among the highest in the sample, and is more than 4 times higher than the MSPE of the countries in the control sample. Only three countries achieve a higher MSPE (i.e. Norway, Madagascar and Philippiness) and they did not introduce a large-scale e-procurement take-up such as the one adopted by Singapore.

In Figure 5, we present the distribution of p-values under a random permutation test. The obtained probabilities indicate the likelihood that the post-treatment effects of e-procurement take-up are obtained at random. More specifically, the p-value represents the proportion of quasi-

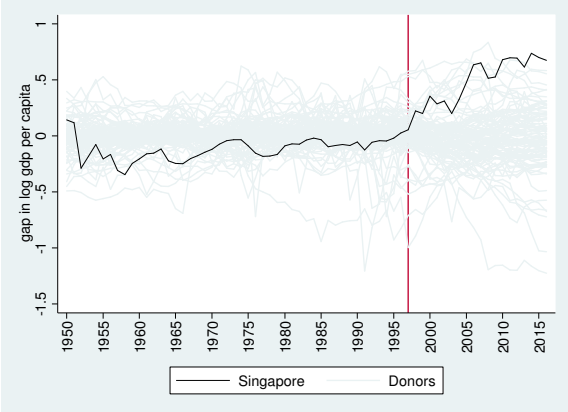
treated countries from the donor pool with the obtained post-1998 per capita GDP effects at least as large as that of Singapore. If the growth effects of 1998 e-procurement implementation are similarly observed in other countries without such large-scale policy intervention, then the observed p-values would be high and could indicate the inability of synthetic control method to capture the growth effects of e-procurement. Conversely, if the obtained p-values are low, this indicates that the post-1998 per capita GDP effects are specific to Singapore, which we interpret as evidence of significant growth effects of the policy intervention. We present the full set of p-values that coincide with each MSPE cutofff used in Figure 3. The proportion of countries with the same post-treatment effect of e-procurement take-up as the effect obtained for Singapore is between 2.9 percent, and 3.9 percent, respectively, which largely confirms the beneficial growth impact of e-procurement reform that appears to be easily perceptible and is specific to Singapore.

Figure 3: Placebo distributions of the GDP per capita gap

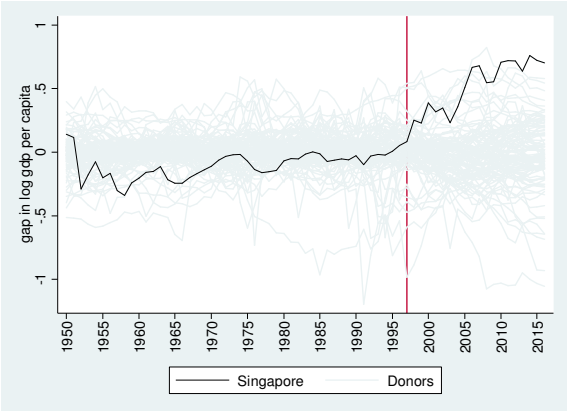
(a) Full control sample



(b) Excluding countries with pre-1998 MSPE>20 higher than Singapore's



(c) Excluding countries with pre-1998 MSPE>5 higher than Singapore's



(d) Excluding countries with pre-1998 MSPE>2 higher than Singapore's

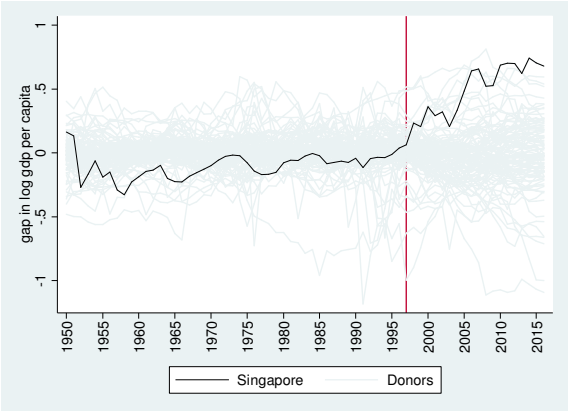


Figure 4: Ratio of post-e-Procurement MSPE and pre-e-Procurement MSPE: Singapore and Control Sample

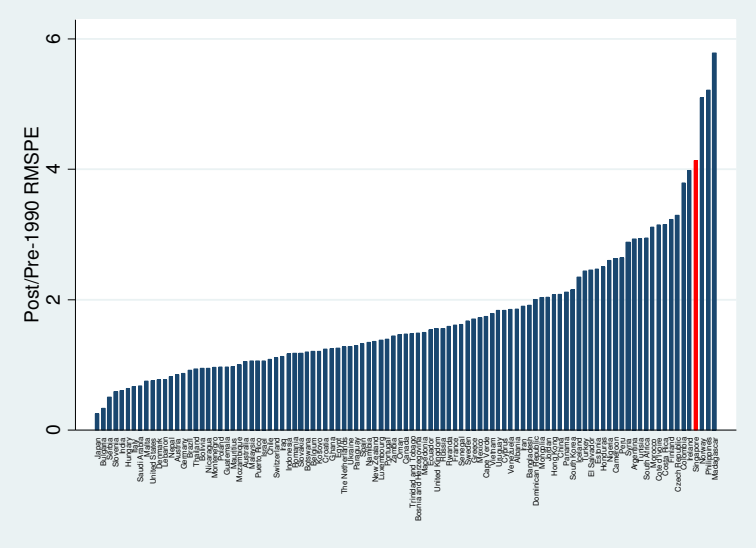
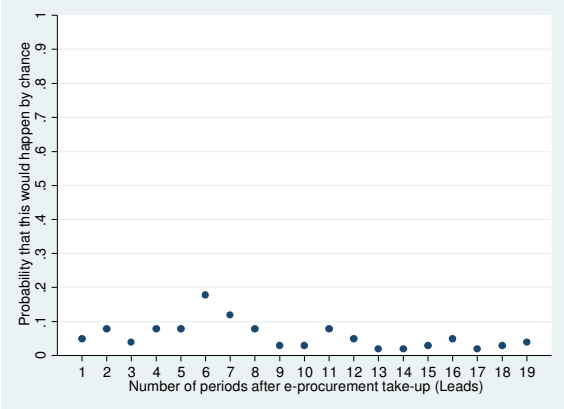
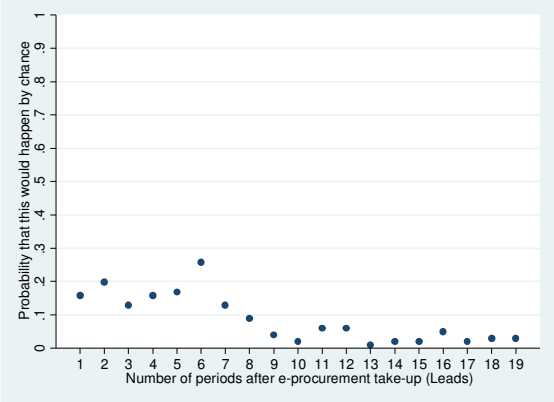


Figure 5: Randomization Inference

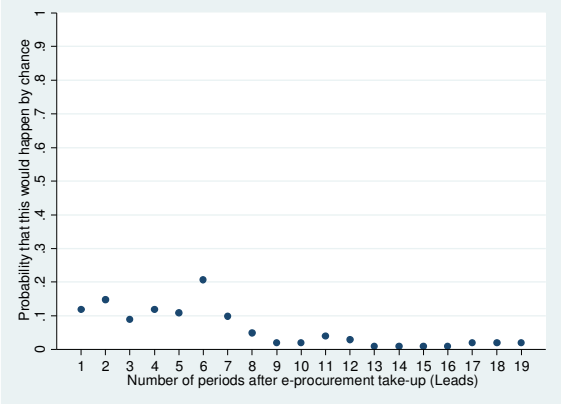
(a) Full control sample



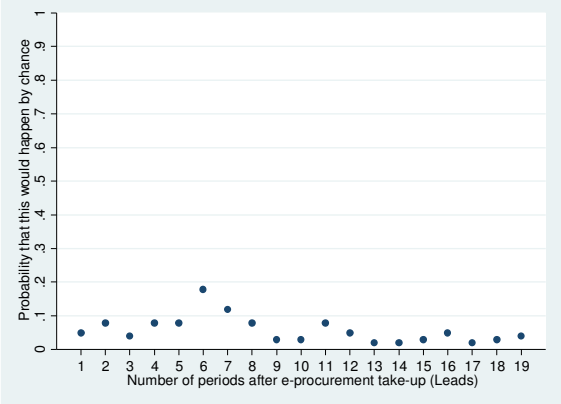
(b) Excluding countries with pre-1998 MSPE>20 higher than Singapore's



(c) Excluding countries with pre-1998 MSPE>5 higher than Singapore's



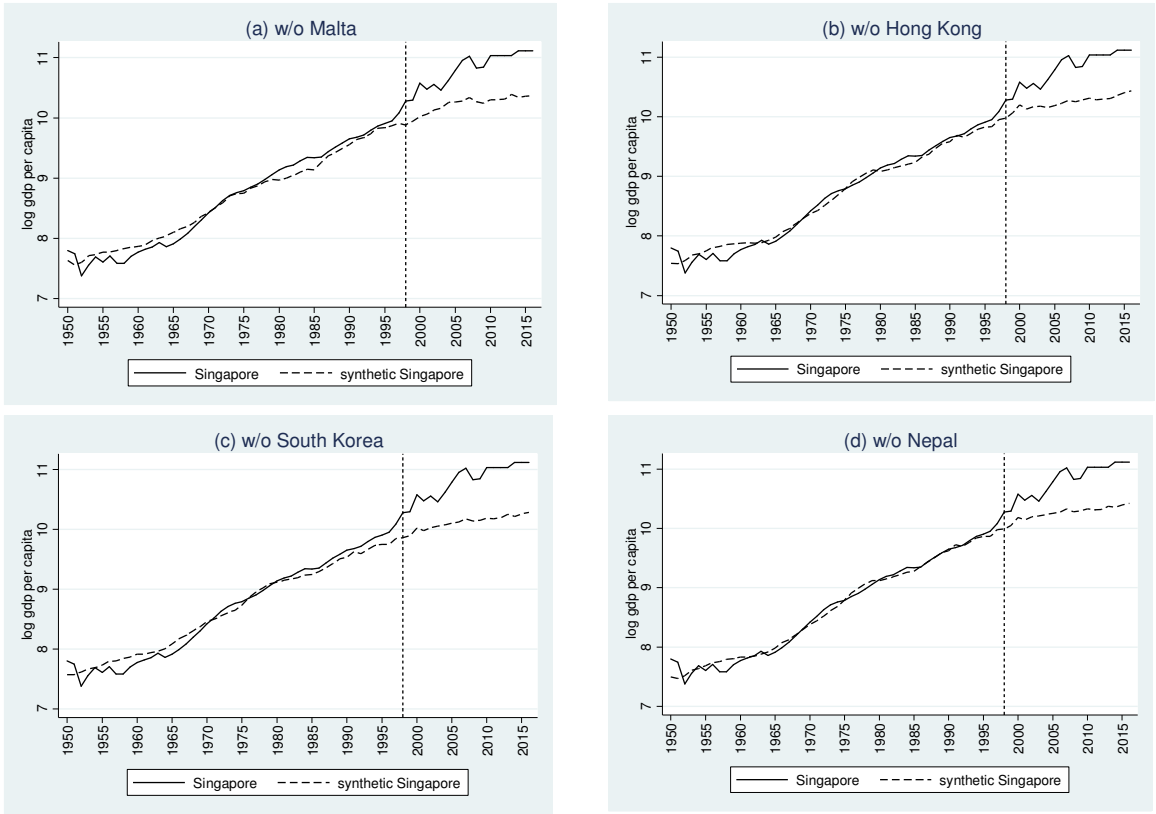
(d) Excluding countries with pre-1998 MSPE>2 higher than Singapore's



5.3 Leave-one-out analysis

Lastly, we examine the sensitivity of baseline synthetic control estimates to the composition of the synthetic control group. Following Klößner et. al. (2018), we exclude each individual country from the donor pool and re-estimate the growth impact of e-procurement reform on the restricted control sample without one donor. Recall that the synthetic Singapore in the baseline estimates consists of a weighted average of covariate-level characteristics of Malta, Hong Kong, South Kora and Nepal. To assess the robustness of our estimates to the composition of the synthetic control group, we iteratively exclude each of the four countries from the donor pool, and re-run the synthetic control estimator on the restricted control sample. Figure 6 presents the re-estimated growth impact of introducing e-procurement by leaving each of the four countries out of the sample. Our preferred estimates are reported in panel (a), which excludes Malta from the donor. Since Malta arguably has the highest weight share (i.e. 0.45) in the composition of synthetic Singapore in the baseline setup, the exclusion has important implications for the internal validity of our estimates. The adjusted synthetic control estimates, reported in Table 2, are entirely consistent with the baseline results both in terms of magnitude and direction. By 2016, the per capita GDP of real Singapore is about 1.2 times higher compared to the synthetic control group without Malta, which consists of Hong Kong (0.48), South Korea (0.38), and Cape Verde (0.14).

Figure 6: Leave-one-out-analysis of growth impact of e-procurement



Panel (b) drops Hong Kong off the donor pool. The per capita GDP gap between Singapore and the synthetic control group is still very high**.** The countries that appear in the synthetic control group are Malta (0.56), South Korea (0.31), and Luxembourg (0.13). In Panel (c), South Korea is excluded from the donor pool. The estimated gap between real Singapore is its synthetic peer is 1.3 times, which appears to be in line with our baseline result. The synthetic control group consists of Malta (53%), Hong Kong (30%), and Thailand (17%). Very similar results and almost identical synthetic control group are obtained in panel (d), where Nepal is excluded from the donor pool.

Table 2: Composition of Alternative Synthetic Control Groups

	w/o Malta	w/o Hong Kong	w/o South Korea	w/o Nepal
Pre-1998 RMSPE	0.035	0.109	0.125	0.125
Estimated Growth Impact	118%	108%	138%	135%
Albania	0	0	0	0
Argentina	0	0	0	0
Australia	0	0	0	0
Austria	0	0	0	0
Bangladesh	0	0	0	0
Belgium	0	0	0	0
Bolivia	0	0	0	0
Bosnia and Herzegovina	0	0	0	0
Botswana	0	0	0	0
Brazil	0	0	0	0
Bulgaria	0	0	0	0
Cameroon	0	0	0	0
Canada	0	0	0	0
Cape Verde	0.14	0	0	0
Chile	0	0	0	0
China	0	0	0	0
Colombia	0	0	0	0
Costa Rica	0	0	0	0
Cote d'Ivoire	0	0	0	0
Croatia	0	0	0	0
Cyprus	0	0	0	0
Czechia	0	0	0	0
Denmark	0	0	0	0
Dominican Republic	0	0	0	0
Ecuador	0	0	0	0
Egypt	0	0	0	0
El Salvador	0	0	0	0
Estonia	0	0	0	0
Finland	0	0	0	0
France	0	0	0	0
Germany	0	0	0	0
Ghana	0	0	0	0
Greece	0	0	0	0
Guatemala	0	0	0	0
Honduras	0	0	0	0
Hong Kong	0.48	0	0.30	0.29
Hungary	0	0	0	0

Iceland	0	0	0	0
India	0	0	0	0
Indonesia	0	0	0	0
Iran	0	0	0	0
Iraq	0	0	0	0
Ireland	0	0	0	0
Israel	0	0	0	0
Italy	0	0	0	0
Japan	0	0	0	0
Jordan	0	0	0	0
Kosovo	0	0	0	0
Lebanon	0	0	0	0
Luxembourg	0	0.13	0	0
Macedonia	0	0	0	0
Madagascar	0	0	0	0
Malaysia	0	0	0	0
Malta	0	0.56	0.53	0.53
Mauritius	0	0	0	0
Mexico	0	0	0	0
Mongolia	0	0	0	0
Montenegro	0	0	0	0
Morocco	0	0	0	0
Mozambique	0	0	0	0
Namibia	0	0	0	0
Nepal	0	0	0	0
New Zealand	0	0	0	0
Nicaragua	0	0	0	0
Nigeria	0	0	0	0
Norway	0	0	0	0
Oman	0	0	0	0
Panama	0	0	0	0
Paraguay	0	0	0	0
Peru	0	0	0	0
Philippines	0	0	0	0
Poland	0	0	0	0
Portugal	0	0	0	0
Puerto Rico	0	0	0	0
Romania	0	0	0	0
Russia	0	0	0	0
Rwanda	0	0	0	0
Saudi Arabia	0	0	0	0
Senegal	0	0	0	0
Serbia	0	0	0	0
Slovakia	0	0	0	0
Slovenia	0	0	0	0
South Africa	0	0	0	0
South Korea	0.38	0.31	0	0
Spain	0	0	0	0
Sweden	0	0	0	0
Switzerland	0	0	0	0
Syria	0	0	0	0
Thailand	0	0	0.17	0.17
The Netherlands	0	0	0	0
Trinidad and Tobago	0	0	0	0
Tunisia	0	0	0	0

Turkey	0	0	0	0
Ukraine	0	0	0	0
United Kingdom	0	0	0	0
United States	0	0	0	0
Uruguay	0	0	0	0
Venezuela	0	0	0	0
Vietnam	0	0	0	0
Zambia	0	0	0	0
Zimbabwe	0	0	0	0

6 Conclusion

In this paper, we examine the contribution of e-procurement policy to economic growth. To this end, we exploit the introduction of a comprehensive and ambitious e-procurement portal in Singapore in 1998. In the respective year, Singapore pioneered the move of public sector procurement process online, extending from publicizing the tender, to the bids delivery and invoicing and payment of suppliers invoices. Our identifying assumption comes from the parallel long-run growth and development, and institutional trends before the e-procurement take-up to construct a counterfactual growth scenario. By matching Singapore with the rest of the world on a battery of pre-policy growth and development characteristics, we are able to empirically isolate the impact of e-procurement policy on growth by comparing Singapore with countries having similar economic outcomes, physical geographical characteristics and institutional quality.

Our results indicate large and pervasive gains from implementing e-procurement policy in terms of higher growth. More specifically, we find that the level of per capita income of Singapore in the post-policy period vastly outperforms its synthetic peer. Our estimates imply that the per capita income gap between Singapore and its synthetic control group tends to widen over time, and indicates large-scale and permanent economic growth benefits of the e-procurement policy change. In particular, our synthetic control estimates suggest that down to the present day, Singapore's per capita income is 1.03 times higher than its counterpart implied by the synthetic control group without a similar e-procurement policy, and does not seem to be much affected by the alternative composition of the control sample.

Furthermore, we assess the statistical significance of our synthetic control estimates and undertake a random permutation test where we assign the e-procurement policy take-up to all unaffected countries, and compute the corresponding per capita income gaps. To tackle a relative rarity of estimating a large post-1998 gap, we set the prediction error cutoff down to the most demanding levels, and build the in-space distribution of placebo gaps. The evidence based on this particular kind of randomization inference suggests that the estimated growth impact of e-procurement policy is specific to Singapore, and does not seem to be prevalent in other countries that did not undertake such a comprehensive reform. In particular, the probability that the estimated effects are obtained at random rather than in response to the policy change is between 2.9 percent and 3.9 percent, respectively, which is well within the conventional 5% threshold. Lastly, our results provide evidence in support of the notion that well-designed and enforced

transparent regulatory policies that provide for low transaction costs, broad-based access to e-procurement and rigorous selection criteria, can generate substantial and possibly permanent growth premium with long-lasting consequences.

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