Infrastructure Investments and Private Investment Catalyzation:

The Case of the Panama Canal Expansion

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Abstract

Large infrastructure projects may change private investors' expectations, even before projects are completed, generating important multiplier effects in the economy. This paper provides the first causal estimates of both the private investment catalyzation effects and the general economic impacts brought by the announcement of the expansion of the Panama Canal, one of the largest infrastructure projects in Latin America and the Caribbean. The empirical approach relies on the synthetic control method as a way to systematically choose among comparison countries and allow for exact inference techniques in small-sample settings. Our results indicate that the announcement of the Canal expansion project, which was formalized by a national referendum in 2006, stimulated significant increases in Private Gross Fixed Capital Formation. Increases account for approximately US$10 billion between 2006-2011 and up to US$47 billion between 2006-2016, mainly driven by increases in construction investments. We also observe important effects in overall economic activity measured by the Gross Domestic Product (GDP). Results are robust to multiple placebo and robustness tests.

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1 Introduction

Infrastructure investments can have important impacts on economic growth (Krugman, 1991; Aschauer, 1993; Fernald, 1999; Donaldson, 2018). The sources explaining this growth can be varied, but in many cases are driven by the attraction of private sector investments that generate multiplier effects in economic activity (Khan & Reinhart, 1990). As Aschauer (1989) suggested in a seminal paper, infrastructure capital can have an important complementary relationship with private capital in the private sector production function; therefore, higher infrastructure investments may raise the productivity of private capital and crowd-in private investment. In addition, large infrastructure investments could improve the business and investment climate by lowering levels of risk and costs of entry or costs of expansion for the private sector (Smith & Hallward-Driemeier, 2005).

When evaluating the effects of large infrastructure projects on attracting private sector investments it is important to acknowledge that these projects might take a considerable amount of time to be built. During this period, private investors can quickly speculate on possible effects, even before the project is completed, leading to a first market response or anticipation effect (Devaux *et al.*, 2017). For example, the announcement of a new metro line may bring changes in real estate prices even before the system is in operation (Damm *et al.*, 1980). Agostini & Palmucci (2008) suggested that the impact of a large infrastructure project, such as a new metro, can be broken down into three distinct phases: announcement period; construction period; and operation period. Thus an adequate framework of analysis needs to account for the cumulative effect, otherwise it could lead to a significant underestimation of impacts.

This paper evaluates the effects on private investment catalyzation and overall economic activity of the Panama Canal expansion project. The project was the largest infrastructure investment in the country since the Canal's opening in 1914, with total project costs accounting for 30% of the country's Gross Domestic Product (GDP) in 2006 when it was announced. This exceptional investment was expected to bring a major boost in income and economic activity. It was also expected to be catalytic by inducing private investments in canal and non-canal related industries and services. The objectives of the study are twofold. First, to present novel causal evidence on the economic effects brought by the Panama Canal expansion. Second, to contribute to the literature on the determinants of private investment and economic multiplier effects arising from large infrastructure investments, while tackling the methodological challenges associated with the estimation of causal effects and the quantification of anticipation effects.

The Panama Canal is one of the most crucial water ways in the Western Hemisphere, connecting the Atlantic and Pacific Oceans. In 2007, the total amount of cargo transported through the Canal was 312 million tons, representing 5% of world seaborne trade (Harjunen, 2006). For Panama, the Canal is at the center of its economic activity, accounting for almost 20% of GDP in direct and indirect contributions.[1] The expansion project was formally

[1] Estrategia Logistica Nacional (2017)

approved by a national referendum in 2006 and was completed in 2016. Our empirical strategy exploits the sharp break given by the referendum date, which formally signaled to the country and to the world that the expansion of the Canal was a reality. Thus, we look at trends before and after this key date to quantify impacts on private Gross Fixed Capital Formation (GFCF) and GDP using the Synthetic Control Method (SCM) developed by Abadie & Gardeazabal (2003) and extended in Abadie *et al.* (2010) and Abadie *et al.* (2015). Following the intuition used in structural break analysis for time series data, we argue that the referendum was a sufficiently relevant event that changed both country and private sector expectations and thus investment decisions.

To implement the SCM we construct a country-level panel dataset covering the period of 1990 to 2016 and using publicly available data. Our results indicate that the announcement of the Canal expansion project, which was formalized by a referendum in 2006, induced important anticipation effects in the Panamanian economy. More specifically, in the medium-term, between 2006 and 2011, we quantify a US$9.9 billion increase in private investment and an increase of US$20.2 billion in GDP that can be attributed to the expansion announcement. Looking at a longer time frame, from 2006 to 2016, the results suggest an accumulated increase in private investment of US$46.6 billion and of US$87 billion in the GDP. These last numbers represent the maximum possible impact value since the ability to attribute effects decreases as we get further from the referendum date and other relevant events occur in the country. Multiple inference and placebo tests confirm our main results. Overall, these findings highlight the important role that the Canal expansion project has had in stimulating Panama's economy. In addition, they showcase the importance of the private sector in driving these economic impacts and the value of capturing anticipation effects in contexts where projects may bring immediate changes in investor expectations.

Our work provides multiple contributions to the existing literature. To start, this is the first paper to empirically estimate the causal impacts brought by the Panama Canal expansion project. During project design and construction, several studies were commissioned by the Panamanian Government and International Organizations to estimate the potential economic impacts (Empresariales, 2006; Sabonge & Sánchez, 2009; Nathan Associates, 2011). These studies used Computable General Equilibrium Models, validated with variables produced by an input-output model. Given the sensitivity of results to model assumptions, different studies provided different predictions. The results from these studies where later integrated and published in a paper by Pagano *et al.* (2012), which estimated impacts for three points in time. First, they looked at the construction period (2010) assessing the impact of construction expenditures on employment and GDP.[2] Next, they examined the post-construction period (2015) to explore what could happen to economic growth shortly after the Canal expands and traffic increases. Finally, they focused on the long-term outlook period (2025) to analyze impacts after full capital adjustment. To the best of our knowledge, there are currently no empirical studies providing a retrospective view of what actually happened in the country and what the causal effects were. Moreover, none of the studies

[2] They do not quantify changes in investments during this period, but they highlight the possible Dutch Disease effect emerging from the increase in wages in the construction sector that reduces the competitiveness of other sectors, such as agriculture, which is the largest employment sector in Panama.

computed impacts on private investment attraction during construction, which could have been one of the main drivers of economic growth.

Second, this paper fits in the literature on the determinants of private investment. Multiple cross-country studies have pointed out that the level of private investment is positively correlated with the level of government investment, but that there might be a long-run complementarity between public and private capital and a short-run substitutability that could lead to a crowd out effect (Greene & Villanueva, 1991).[3] The majority of studies, based on correlation or cointegration analyses, find complementarities between public investments, particularly infrastructure investments, and private investments (Greene & Villanueva, 1991; Blejer & Khan, 1984; Oshikoya, 1994; Ghura & Goodwin, 2000; Ang, 2009; Aschauer *et al.*, 1989).[4] Another set of studies show that public capital affects industries differently and industries react differently to different components of public investments. For example, the manufacturing, construction, and real estate industries seem to benefit more from public investment in highways, and water and sewer systems, while agriculture seems not to benefit as much (Shah, 1992; Evans & Karras, 1993; Pereira *et al.*, 2007).

This study also contributes to the literature on anticipation effects, which has been concentrated around urban transport investments and their effects on real estate markets. Some of this evidence shows significant capitalization effects before a new transport system starts operating (McMillen & McDonald, 2004; Damm *et al.*, 1980; McDonald & Osuji, 1995; Boarnet & Chalermpong, 2001; Yiu & Wong, 2005; Agostini & Palmucci, 2008; Golub *et al.*, 2012), whereas other studies, such as Gatzlaff & Smith (1993) find no effects from the announcement of the new train system in Miami, and Boucq & Papon (2008) also noted no anticipation effect for the construction of the T3 line in Haut-de-Seine, suggesting that negative externalities related to construction can eliminate the potential positive effects. Finally, it is important to mention that there are still relatively few causal evaluations in the infrastructure sector, probably responding to several methodological challenges that arise due to the non-random placement of infrastructure projects and small sample sizes. The majority of causal evidence available is concentrated around highways and urban transport systems, but few studies have explored the impacts of logistics infrastructure (Sainz *et al.*, 2013).

The rest of this paper is organized as follows. Section 2 describes the Panama Canal expansion project under evaluation. Section 3 presents the identification strategy and describes the data. Section 4 shows the main results, placebo and robustness tests and discusses some of the changes observed in the composition of private GFCF in Panama between 1996 and 2014. Section 5 provides estimations on economy-wide effects of the Canal expansion announcement. Finally, Section 6 presents a discussion of how the results compare to other findings in the literature and the main conclusions.

[3] On the one hand, large public sector investments may translate into large fiscal deficits, credit rationing and higher current or future taxes, thus crowding out private investments. On the other hand, large investments, mainly infrastructure, may be complementary with private investment (Oshikoya, 1994).

[4] Only a few authors, such as Balassa (1988), show a negative relationship, which the authors explain as an unfavorable investment climate created by large public investments.

2 The Panama Canal Expansion Project

In 2006, studies commissioned by the Panama Canal Authority (PCA) anticipated that by 2011, 37% of the world's container ships would be too large for the Canal; therefore, a failure to expand would have resulted in a significant loss of market share. The maximum sustainable capacity of the Canal, prior to the expansion, was estimated at 340 million PC/UMS[5] tons per year and it was anticipated that this capacity would be reached between 2009 and 2012. The expansion project was formally approved in a national referendum on October 22, 2006 and built between 2007 and 2016. The expansion was expected to provide important benefits to Panama and to support increased world trade. More specifically, it was expected to bring a significant increase in funds to the Government of Panama and generate an important direct and indirect increase in employment. In addition, it was estimated that increased canal traffic would have a positive impact on export growth, inducing investments in canal and non-canal related industries and services, and providing the basis for a sustainable and positive economic impact in the country.

The expansion project doubled the capacity of the Canal by increasing the width and depth of lanes allowing for larger ships to pass. Specifically, the project involved:

(i) The widening and deepening of existing navigational channels;

(ii) The expansion of two new flights of locks built parallel to, and operated in addition to, the old locks: one east of the existing Gatun locks (Atlantic side), and one southwest of the Miraflores locks (Pacific side), each supported by approach channels;

(iii) The deepening of Gatun Lake and the raising of its maximum water level, which allow the expanded canal to operate without constructing new reservoirs.

The project was designed to allow for an anticipated growth in traffic from 280 million PC/UMS tons in 2005 to nearly 510 million PC/UMS tons in 2025. The expanded canal has a maximum sustainable capacity of about 600 million PC/UMS tons per year. The project was expected to open in October 2014, but did not open until June 2016, due to cost overruns and construction glitches. In 2017, the total cost of the project was estimated at US$5.5 billion.[6] Of the total amount, US$2.3 billion (42%) was externally financed[7] and US$3.2 billion (58%) was funded by the PCA with internal resources.

[5] The Panama Canal/Universal Measurement System (PC/UMS) is based on net tonnage, modified for Panama Canal purposes. PC/UMS is based on a mathematical formula to calculate a vessel's total volume; one PC/UMS net ton is equivalent to 100 cubic feet of capacity.

[6] Information extracted from the Completion Report. Common Terms Agreement among Autoridad del Canal de Panama and Credit Facility Lenders (2017). The original project cost was estimated to be US$5.25 billion.

[7] The external financing includes loans from the following institutions: (1) Japan Bank for International Cooperation (JBIC) −US$800 million (35%); (2) European Investment Bank (EIB) −US$500 million (22%); (3) Inter−American Development Bank (IDB) −US$400 million (17%); (4) Corporación Andina de Fomento (CAF) −US$300 million (13%); and (5) International Finance Corporation (IFC) −US$300 million (13%).

3 Identification Strategy

3.1 Synthetic Control Method

One of the main challenges in quantifying private capital anticipation effects is attribution. Sometimes additional increases in private investments beyond the boundaries of direct project financing can be difficult to quantify and to causally attribute to the intervention. To overcome this problem, we implement a Synthetic Control Method (SCM), which is a data-driven approach that allows us to construct a suitable comparison group that can reproduce the counterfactual trajectory that Panama would have experienced in the absence of the canal expansion project (Abadie *et al.*, 2010, 2015). We exploit the formal announcement of the Panama Canal expansion project given by the referendum in October of 2006. We expect this event to be sufficiently relevant to change country and private sector expectations and thus investment decisions.

Motivated by comparative case study research, the key idea behind SCM is that a weighted combination of unaffected units may resemble the characteristics of the treated unit substantially better than any untreated unit alone. The methodology works by assigning an analytical weight to each untreated country to construct the synthetic version of the treated unit (i.e. Panama). These weights are chosen in order to minimize the difference in pre-intervention characteristics between the treated unit and the pool of potential comparison countries. Under the assumption that in absence of the intervention Panama and its synthetic counterpart would continue to follow a similar trend, the SCM enables us to identify the impact of the Canal expansion as the difference between Panama and its synthetic counterpart. The SCM has been increasingly implemented in different areas in economics in recent years (Castillo *et al.*, 2017; Bohn *et al.*, 2014; Cavallo *et al.*, 2013; Billmeier & Nannicini, 2013; Hinrichs, 2012).

Formally, suppose that there is a sample of $J+1$ units (e.g. countries) indexed by j, where $j = J+1$ is the country of interest (i.e. Panama) and the J remaining countries constitute the set of potential comparisons (i.e. "donor pool"). Assume that we have a longitudinal data set where all units are observed at the same time periods, $t = 1, ..., T$. The sample includes T_0 pre-intervention periods and T_1 post-intervention periods, with $T = T_0 + T_1$. Unit $P = J+1$ (i.e. Panama) is exposed to the intervention of interest (the "treatment") during periods $T_0+1, ..., T$, and the intervention has no effect during the pre-treatment period $1, ..., T_0$.

Let Y_{it} be defined as the observed outcome variable for country i at time t and Y_{Pt}^N the counterfactual outcome, that is, the outcome that would have been observed for the treated unit ($j = P$) after T_0 in absence of the intervention. Then, the effect of the Canal expansion on the outcome variable is given by:

$$\tau_t = Y_{Pt} - Y_{Pt}^N \tag{1}$$

Since Y_{Pt}^N is unobservable by definition, we use the SCM to estimate it. Synthetic Panama is a weighted average of the countries in the donor pool. That is, synthetic Panama can be represented by a $(J \times 1)$ vector of weights $W = (w_1, ..., w_J)$, with $0 \leq w_j \leq 1$ for $j = 1, ..., J$

and $w_1 + ... + w_J = 1$. The value of W is chosen such that the characteristics of the treated unit are best resembled by the characteristics of the synthetic control. Thus, let X_P be a $(k \times 1)$ vector containing the values of the pre-intervention characteristics of the treated unit that we aim to match as closely as possible and let X_S be the $(k \times j)$ matrix collecting the values of the same variables for the units in the donor pool.[8] The difference between the pre-intervention characteristics of the treated unit and a synthetic control is given by the vector $X_P - X_S W$. The synthetic control is selected so that W^* minimizes this squared difference:

$$\sum_{m=1}^{k} v_m \left(X_{Pm} - X_{Sm} W\right)^2 \quad (2)$$

Where v_m is a weight that reflects the relative importance given to the m-th variable when measuring the discrepancy between X_{Pm} and $X_{Sm}W$. This weight is relevant as the synthetic control should closely reproduce the values of variables that have large predictive power on the outcome of interest. In this context, the choice of pre-treatment characteristics crucially determines the weights and composition of the synthetic control. Once W^* is computed, the pre-intervention trend and the post-intervention trend for the outcome variable for the synthetic control can be obtained by calculating the corresponding weighted average for each year, using the donor countries with positive weights. Finally, the treatment effect could be estimated as:

$$\widehat{\tau}_t = Y_{Pt} - \widehat{Y}_{Pt}^N = Y_{Pt} - \sum_{j=1}^{J} w_j^* Y_{jt} \quad (3)$$

3.2 Inference and Placebo Tests

Abadie *et al.* (2015) demonstrate that the main barrier to quantitative inference in comparative studies comes not necessarily from the small-sample size of the data, but from the absence of an explicit mechanism that determines how comparison units are selected. Thus, by carefully specifying how units are selected for the comparison group, the SCM allows us to perform exact quantitative inference, which is similar in intuition to conducting permutation tests. The main premise is that our confidence that a particular synthetic control estimate reflects the true impact of the intervention of interest would be undermined if we obtained estimated effects of similar or even greater magnitudes in cases where the intervention did not take place.

We evaluate the significance of our results by running an “in-space placebo” test, which involves applying the SCM to estimate placebo effects for every potential control unit in the donor pool and compare this with the results obtained for Panama. This allows us to create a distribution of placebo effects against which we can then evaluate the effect estimated for Panama. By comparing the Root Mean Square Prediction Error (RMSPE)[9] for the treated

[8] The pre-intervention characteristics in X_P and X_S may include pre-intervention values of the outcome variable.

[9] RMSPE measures the quadratic discrepancies between the treated unit (Panama) and its synthetic version.

unit with those from the placebos, we can derive the likelihood that the estimate would have been observed if there had been no expansion project. In particular, we rank the ratios between post and pre-treatment RMSPE for every placebo and the implied p-values are constructed by computing the proportion of ratios that are higher than the estimated gap for Panama. Second, we produce an "in-time placebo" where we apply the SCM assuming that the expansion announcement happened in a year other than 2006. If there is a divergent trend starting in other years this would be an indication that our results were obtained by chance and cannot be attributed to the expansion announcement.

3.3 Data and Donor Pool Construction

We use worldwide country-level data from 1990 to 2016 extracted from the World Development Indicators (WDI) (WB, 2018) and the World Economic Outlook (WEO) (IMF, 2018) database. Our main outcome of interest is private Gross Fixed Capital Formation (GFCF) at Purchasing Power Parity (PPP) US$, which is used as a proxy of private investment, and measures the value of acquisitions of new or existing fixed assets by the private sector less disposals of fixed assets. As covariates or predictors of the outcome of interest, we include data on: public GFCF, GDP per capita, population, trade openness (real exports plus real imports over real GDP), variations in the exchange rate, consumption, and interest rate. Following Kaul *et al.* (2018) we do not include the entire pre-treatment path of the outcome variable as predictors, and only include the average, as this would render all other covariates irrelevant and could lead to bias in our estimates. Rather, we include the average of the pre-treatment period value of private GFCF.

To construct the donor pool and minimize bias caused by interpolating across countries with very different characteristics (Abadie *et al.*, 2015), we only include emerging countries such as Panama in the sample, and countries that have a cargo or container port, according to the 2008 World Port Ranking published by the American Association of Port Authorities (AAPA). This ranking reports the top 125 ports in the world, based on total cargo volume or container traffic and covers 53 countries. In addition, we include countries that are financial centers according to the 2013 Global Financial Centers Index, which is the year when Panama entered this group. We exclude all countries with less than 10 observations between 1990 and 2006 (both for outcome and/or control variables); countries created after 1990; and countries without observations between 2001 and 2006.[10] Table **??** in Appendix A reports the list of countries that have at least 10 observations in the period 1990-2005 across the covariates used for the SCM analysis. It also shows the countries that have ports or are considered financial centers and are included in the donor pool.

[10] To handle missing values we decided to use the following imputation strategy. We replace each missing value with the mean between the first non-missing values observed before and after. In the pre-treatment, if there were no values before, we replace the missing value with the first available value. In the post-treatment, if there were no values after, we use the last non-missing value.

4 Results

4.1 SCM for Private Gross Fixed Capital Formation

Figure 1 reports the evolution of private GFCF for Panama and the donor pool of countries before implementing the SCM. From this figure, we can see that the entire donor pool would not be a suitable comparison group for Panama. In fact, even prior to the Canal expansion, the time series of private GFCF in Panama was quite different than the donor pool, showing a relatively flat trend. Following the Abadie *et al.* (2010) methodology we construct synthetic Panama as the convex combination of countries in the donor pool that best reproduces the values of predictors for private GFCF in Panama in the pre-announcement period. Table 1 displays the mean values of all pre-treatment characteristics for actual and synthetic Panama, as well as the average values for the entire donor pool. The last column presents the optimal weight distribution for included covariates (as captured in the diagonal matrix V).

Figure 1: Evolution of Private Gross Fixed Capital Formation
Panama and Donor Pool

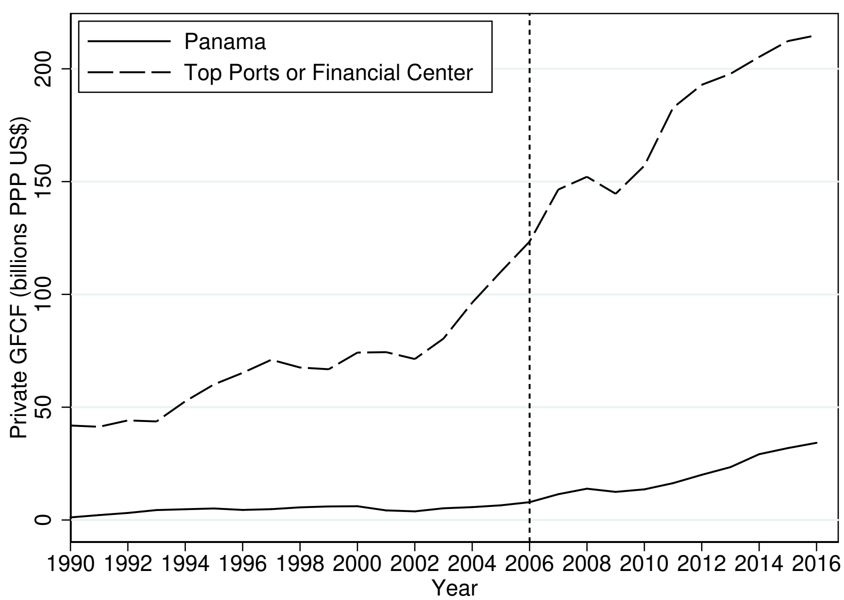


Table 1 shows that the synthetic control is a better counterfactual for Panama than the unweighted average of the donor pool. Synthetic Panama is able to reproduce more accurately the average pre-treatment values (or pre-announcement values) for almost all the characteristics of private GFCF. The weights chosen indicate that the most important predictors (in order from highest to lowest weight) are: the average of the pre-treatment period value of private GFCF, consumption, population, growth in exchange rate, public GFCF, and real interest rate. We also see that GDP per capita is the only characteristic that the synthetic version is not able to reproduce better than the unweighted average of the donor pool. However, the weight that this variable received in the optimization process is zero, thus it does not appear to have substantial predicting power with regards to pre-treatment private GFCF.

Table 1: Predictors Private GFKF before Panama Canal Expansion (1990-2005 average)

	Donors	Panama		V Matrix
		Actual	Synthetic	Weights
Private GFCF (in billions 2010 PPP)	66.32	4.58	4.60	0.24
Public GFCF (in billions 2010 PPP)	20.08	0.49	1.36	0.10
GDP per capita	5,895	5,083	5,929	0.00
Real Interest Rate (1995-2005)	11.26	9.34	10.39	0.02
Trade Openness*	0.58	1.43	1.14	0.00
Exchange Rate Growth	0.57	0.00	0.04	0.19
Consumption (in billions 2010 PPP)	149.06	9.64	8.47	0.23
Population (in millions)	84.58	2.89	4.85	0.21

*Note: Trade openness is calculated as the quotient of the sum of real exports and real imports, over real GDP.

Table 2 displays the countries that make up synthetic Panama in the specification that renders the best fit (as expressed by the smallest mean squared prediction error, or MSPE), followed by its respective weight. Private GFCF in Panama in the pre-announcement period is best reproduced by a combination of Mauritius, Sri Lanka, The Bahamas, and Malaysia (presented in order of importance). All other countries in the donor pool obtain zero weights.

Table 2: Countries in the Synthetic Control for Private GFCF

	W Weight
Mauritius	0.693
Sri Lanka	0.202
The Bahamas	0.09
Malaysia	0.015

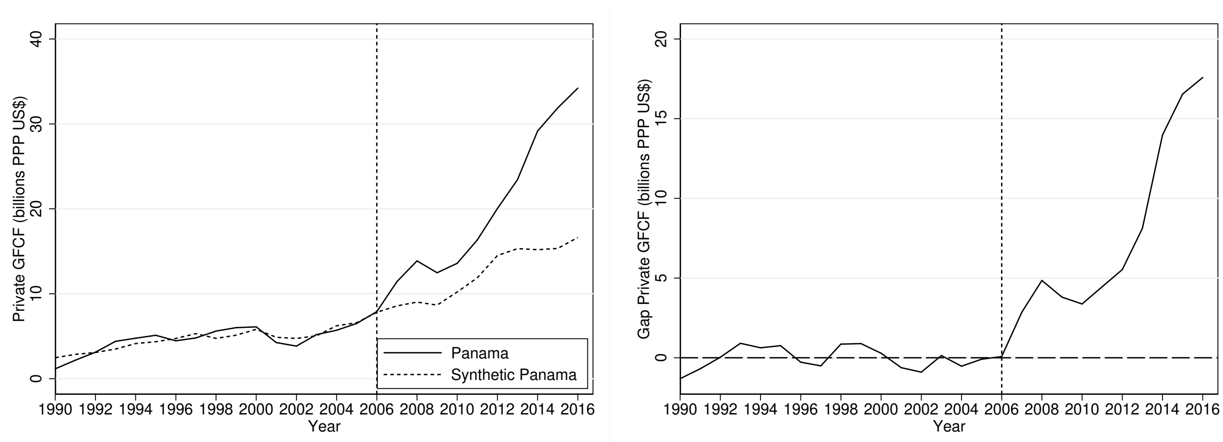
Once we construct the synthetic counterfactual that adequately reproduces pre-announcement private GFCF in Panama, we can estimate the post-announcement impact for 2006 to 2016. Figure 2a presents the private GFCF trajectories for real Panama and its synthetic counterfactual from 1990 to 2016. Synthetic Panama very closely mimics the trajectory of private investment in real Panama 15 years prior to the canal expansion announcement (1990−2005). After 2006, a structural break happens and a divergent trend is evident suggesting that private sector investment responded quite quickly and positively to the prospect of having an expanded canal. There is a small downward trend in investment for Panama in 2009, probably due to the financial crisis,[11] but the increase in private investment in the country is quite

[11] Despite the financial crisis in 2009, the Panamanian economy reported a growth rate of 3.9% that year. Moreover, between 2006 and 2011 Panama exhibited an average growth of 8.9%.

remarkable when compared to the counterfactual situation after the announcement.

Another way of presenting the results is by plotting the yearly gaps in private GFCF between Panama and its synthetic counterpart. Figure 2b plots these gaps and Table 3 presents the results in PPP US$ and current US$. In both cases, we can appreciate that the magnitude of the estimated impact is substantial. The results indicate that in the medium-term, between 2006 and 2011, there was an increase of US$9.9 billion in private investment that can be attributed to the formal announcement of the canal expansion (anticipation effect). This is 1.8 times the size of the total expansion project investment and, on average, 1.3 times the trend that would have been observed in private investment in Panama in the absence of the expansion referendum. Looking at a longer timeframe, from 2006 to 2016, the results suggest an accumulated increase in private investment of US$46.6 billion (8.5 times greater than the total expansion project investment and 1.5 times the counterfactual scenario). These results represent the maximum possible impact value since the ability to attribute effects decreases as we get further from the referendum date and other relevant events occur in the country.[12]

Figure 2: Impacts on Private Gross Fixed Capital Formation



(a) Trends in Private GFCF

(b) Gap in Private GFCF

[12] For example, relevant investments made after 2011 include: the construction of the metro and a new terminal at Tocumen airport, as well as the Cobre Panama copper mining project. However, it is difficult to determine if these investments would have taken place without the canal expansion announcement and if their announcement helped to attract more private investment

Table 3: Impacts on Private GFCF

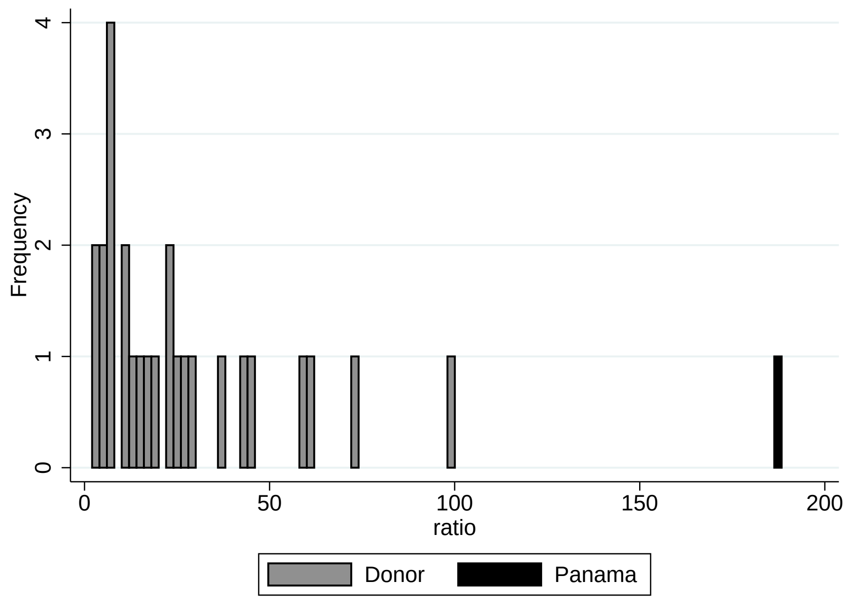
Year	Synthetic	Panama	Effect USD PPP	Effect USD Current
2006	7.82	7.9	0.08	0.04
2007	8.57	11.43	2.86	1.32
2008	9.02	13.87	4.85	2.37
2009	8.67	12.47	3.8	1.97
2010	10.21	13.59	3.38	1.77
2011	11.88	16.34	4.46	2.44
2012	14.5	20.03	5.53	3.16
2013	15.31	23.44	8.12	4.81
2014	15.19	29.16	13.97	8.41
2015	15.34	31.88	16.54	9.87
2016	16.63	34.21	17.58	10.45

4.2 Inference

An "in-space placebo" test allows us to do inference and examine how often results in the same order of magnitude would be obtained if we had chosen another treated country at random instead of Panama. For this, we iteratively apply the SCM to all countries in the donor pool, shifting Panama to the donor pool. Then, we estimate the ratios of post/pre-Canal expansion announcement Mean Square Prediction Error (MSPE) for each country and create a distribution of ratios that shows where Panama's ratio is. Finally, we estimate the probability of obtaining a post/pre-intervention ratio as large as Panama's.[13] Figure 3 reports the distribution of post/pre-intervention ratios of MSPE for Panama and the 26 donor countries. Panama stands out as the country with the highest MSPE ratio. For Panama the post-policy gap is almost 200 times larger than the pre-policy gap. Because this test includes 27 countries, if one were to assign the intervention at random in our data, the probability of obtaining a post/pre-intervention ratio as large as Panama's would be $\frac{1}{27} \cong 0.04$.

[13] Other papers have also looked at the gaps in the outcome of interest between the treated unit and its synthetic version for the different placebo runs, as reported in Figure 2b. The main limitation with this approach is that if there is poor fit of the synthetic version in the pre-treatment period, then any post-intervention gap observed would be artificially created by the lack of fit rather than the effect of the announcement (Abadie & Gardeazabal, 2003). In these cases, the method requires excluding countries where pre-announcement MSPE is large compared to a defined threshold. In our case, and to avoid choosing a cut-off for the exclusion of poor-fitting placebo runs, we report directly the distribution of ratios of post/pre announcement MSPE.

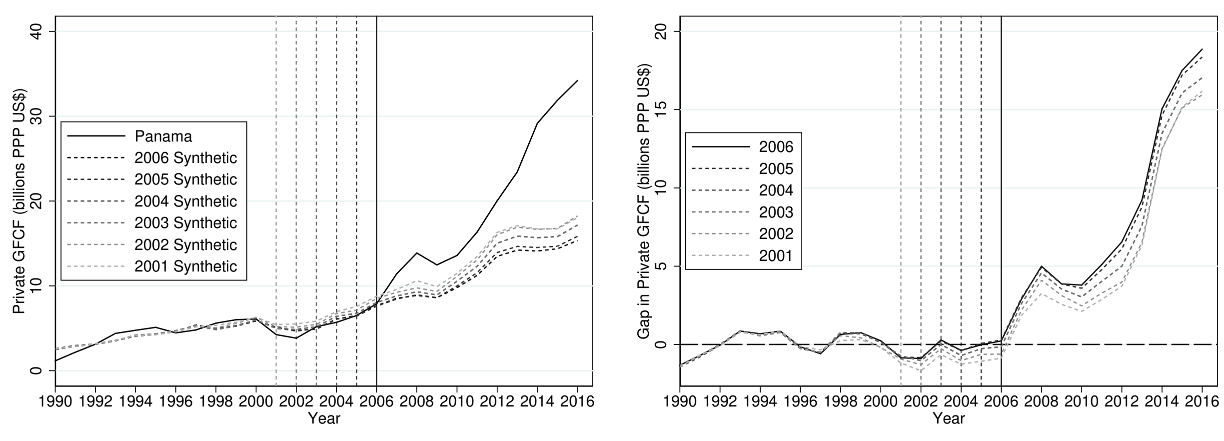
Figure 3: Place Placebo − Private GFCF
(Post/Pre-Canal Expansion Announcement MSPE)



4.3 Robustness and Placebo Tests

We conduct an "in-time placebo" test, which involves applying the SCM assuming that the Canal expansion announcement happened in a year other than to 2006. In this case, if there is a divergent trend starting in previous years this would be an indication that our results were obtained by chance and could not be attributable to the Canal expansion announcement. Figures 4a and 4b display the results of applying SCM using the actual year (2006, shown in solid black) and a set of pre-treatment dates (i.e. our placebo dates), where the darkest lines correspond to placebo estimates computed using a starting date closer to the actual one. We find consistent evidence that synthetic Panama predicts very well the trends of private investment for real Panama over the entire pre-treatment period for all of the analyzed years (placebos), but that the only divergent trend appears in 2006. This means, we find no evidence of diverging trends between Panama and synthetic Panama in a five-year window of placebos prior to the announcement year.

Figure 4: Time Placebo − Private GFCF



(a) Trends in Private GFCF

(b) Gap in Private GFCF

Results are robust to multiple tests which are reported in Appendix B. We implement a cross-validation technique to check the sensitivity of the results to the selection of the v_m weights, which reflect the relative importance given to certain predictors when measuring the discrepancy between Panama and its synthetic version. This weight is relevant as the synthetic control should closely reproduce the values of variables that have large predictive power on the outcome of interest (Private GFCF) and the choice of pre-treatment characteristics crucially determines the weights and composition of the synthetic control. We also show how sensitive results are to changes in the country weights or to data from a particular country (Abadie *et al.*, 2015) by iteratively re-estimating the model omitting in each iteration one of the countries that received a positive weight.

Even though the SCM chooses the optimal weights to minimize the pre-treatment MSPE between the treated unit and its synthetic counterpart, there might still be differences in levels of variables in the pre-treatment period. To solve this potential problem, we follow Garcia Lembergman *et al.* (2015) and implement a Difference-in-Differences approach to subtract pre-announcement differences from post-announcement differences. Finally, we explore whether other important events or investments happened in the country around the year 2006 and that could be confounded with the impacts of the Canal expansion announcement or could lead us to overestimate impacts.

4.4 What is Driving Private Investment Increases?

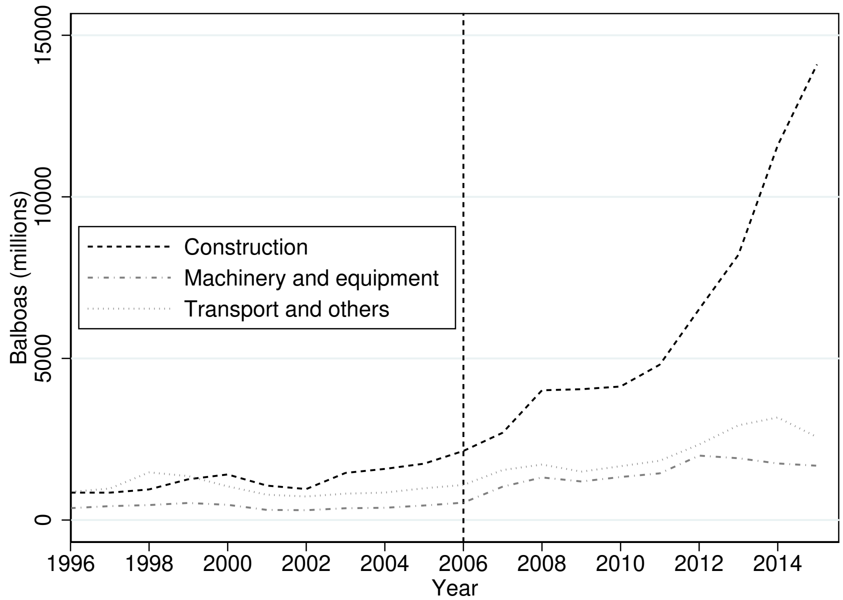
Panama's National Institute of Statistics and Census (INEC) reports yearly disaggregated data on the components of private GFCF. We use this data to visually explore whether there are different changes in the trends for different private GFCF components around the Canal expansion announcement date. As shown in Figure 5, there is an important increase in private investments in the construction sector starting in 2006 and this change in trend is mostly explained due to large increases in non-residential investments after 2006. It is worth mentioning that residential investments also experience an important increase and, although the trend was already positive before the expansion announcement, it is steeper after 2006. Data also shows a positive change in private investments in machinery and equipment as well as in the transport sector, but its magnitude is well below the size of the increase observed for real estate investments.

These trends suggest that most of the expansion in the Panamanian economy, in anticipation of the opening of the expanded Canal, has been driven by private infrastructure investments. This explains the country's current growth model and the fact that Panama's economy is based primarily on a services sector that accounts for nearly 80% of its GDP and it is heavily weighted toward banking, commerce, real estate, and tourism. In addition, the trends observed reflect the increasing need for Panama city to adapt its infrastructure to respond to the wider distribution of goods that is expected to happen given the Canal expansion. As the data shows, these needs have translated into further development of building and industrial spaces for the logistics and services sector in and around port areas, as well as residential housing to accommodate the expanding labor force.

It is important to mention that changes observed in the real estate market of Panama, have also been anticipated and observed in other US East Coast cities that have benefited from the expanded Canal given their interconnection with the transport of goods.[14] This type of analysis is outside the scope of this study, but highlights the transformative role of the Canal expansion project both for the Panamanian economy and also abroad. Regarding the more general impacts on Panama's economy, the next section explores the impacts on GDP using a SCM.

[14] For more information please check $http://www.kristensosulski.com/2018/05/the-effect-of-the-expanded-panama-canal/$

Figure 5: Components of Private Gross Fixed Capital Formation



5 Overall Effect on Panama's Economy

As private investment is a component of GDP, it is reasonable to say that the announcement of the Panama Canal expansion had an overall positive effect on Panama's economy.[15] However, to correctly identify the anticipation effects of the announcement on GDP, we run the SCM again to construct a synthetic Panama for the GDP and estimate the effect on that outcome variable. These results provide us with a better picture of the wider economic effects of the Canal expansion project in Panama.

To conduct this analysis, we use the same data set, but we vary the set of predictors, taking into account what economic theory tells us about the main determinants of GDP and those that help to improve the adjustment of synthetic Panama in the historic series. More specifically, we control for Total GFCF (public and private), exports, imports, government expenditure, consumption, population, country's total land area, country's agricultural land area, and unemployment rate. As we did with private GFCF, we also include as a control the average GDP in the pre-treatment period. Finally, we also include as a predictor a lag of GDP (i.e. GDP level in 2005).[16] Table C1 in Appendix C shows that synthetic Panama is able to accurately reproduce the average pre-treatment values for almost all the characteristics of Panama's GDP.

[15] In particular, private GFCF participation in GDP has increased after the announcement, from around 18% (average 1990-2005) to 29% (average 2006-2016).

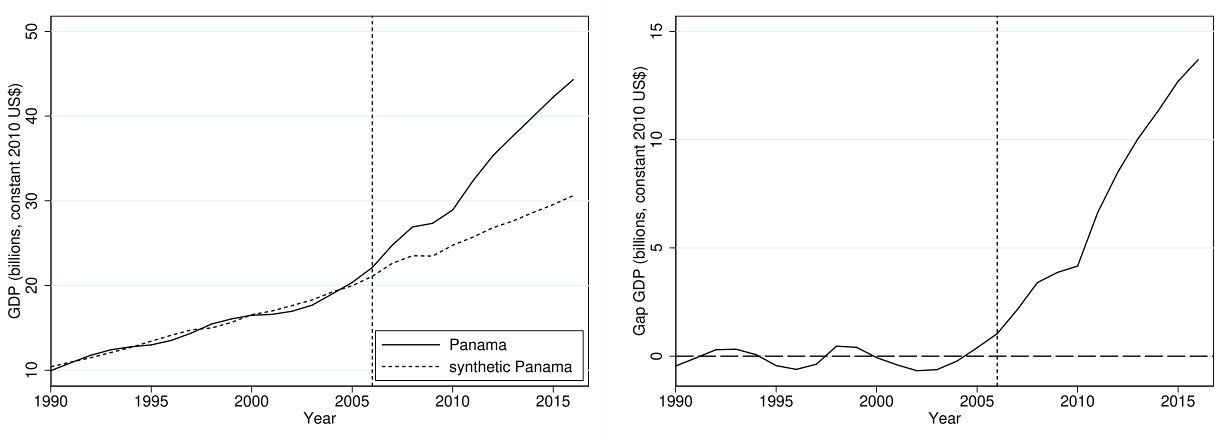
[16] This predictor was not included in the specification chosen for Private GFCF, because it was not needed to improve the adjustment of the synthetic control, nevertheless our results remain unchanged if we include it.

Table 4 displays the countries that are part of synthetic Panama in the specification that renders the best fit for this outcome, followed by its respective weight. We can see that Panama's GDP in the pre-announcement period is best reproduced by a combination of The Bahamas, Mauritius, Costa Rica, Lebanon, Malaysia, Vietnam, Venezuela, and Ukraine (presented in order of importance). Figure 6 presents the GDP trajectories for real Panama and its synthetic counterfactual from 1990 to 2016 and Figure 6 plots the yearly gaps in GDP between real and synthetic Panama. Table 5 presents the results in constant 2010 US$ and in current US$. The results show that in the medium term, between 2006 and 2011, there was an increase of US$20.2 billion in the GDP, which can be attributed to the Canal expansion announcement. This is 1.2 times the trend observed in the counterfactual scenario and 4.4 times the project cost. In the long-run, between 2006 and 2016, there is an accumulated increase of US$87 billion in the GDP (1.4 times the trend of the counterfactual and 15.8 times total project investment). These results represent the maximum possible impact value since, as it was mentioned before, our ability to attribute effects decreases as we get further from the referendum date and other relevant events occur in the country. Results reported in Appendix C show that these results are robust to the multiple placebo and robustness checks that were also conducted for the case of private GFCF.

Table 4: Countries in the Synthetic Control for GDP

	W Weight
The Bahamas	0.386
Mauritius	0.323
Costa Rica	0.171
Lebanon	0.078
Malaysia	0.03
Vietnam	0.016
Venezuela	0.009
Ukraine	0.003

Figure 6: Impacts on GDP



(a) Trends in GDP

(b) Gap in GDP

Table 5: Impacts on GDP (in billions)

Year	Synthetic	Panama	Effect USD Constant 2010	Effect USD Current
2006	21.09	22.13	1.04	0.86
2007	22.63	24.78	2.15	1.86
2008	23.51	26.91	3.4	3.2
2009	23.47	27.34	3.87	3.74
2010	24.76	28.92	4.16	4.16
2011	25.7	32.33	6.63	7.02
2012	26.82	35.32	8.5	9.51
2013	27.62	37.66	10.04	11.68
2014	28.62	39.93	11.32	13.52
2015	29.55	42.24	12.69	15.18
2016	30.61	44.3	13.69	16.5

6 Discussion and conclusions

Large infrastructure investments have great potential to influence the business climate and bring changes to private sector investment and overall economic activity in a given context. To better understand this relationship and its development impact, tackling attribution or causality is key to quantifying, in a precise and rigourus way, the extent to which increased private investment results from specific infrastructure projects. In this paper we propose an empirical strategy to approximate causal private investment catalyzation effects resulting from the expansion of the Panama Canal by implementing the SCM originally proposed by Abadie & Gardeazabal (2003). As large infrastructure projects take a considerable amount of time to be built and private investors can quickly speculate on possible effects even before the project is completed, we pay particular attention to quantifying the effects that appear right after the formal announcement of the project, in this case given by the national referendum in 2006. Not accounting for these impacts would lead to an important underestimation of effects.

Our results indicate that the announcement of the canal expansion project, which was formalized by a referendum in 2006, stimulated important anticipation effects in Panama's economy. More specifically, in the medium term (between 2006 and 2011) we quantify increases in private investment of US$ 9.9 billion. This represents 1.8 times the size of the total investment of the project (US$ 5.5 billion)[17] and is, on average, 1.3 times the trend that would have been observed in private investment in the country in the absence of the expansion referendum. Considering a longer time frame, from 2006 to 2016, we calculate total impacts on private investment of US$ 46.6 billion (8.5 times the size of project costs and 1.5 times the counterfactual scenario). These results represent the maximum possible impact value, since the ability to attribute effects decreases as we move away from the date of the referendum and other relevant events occur in the country far from this date. As a complementary analysis we quantify global impacts on the economy of Panama finding an accumulated increase of US$ 20.2 billion in GDP in the medium term (1.2 times the counterfactual scenario and 4.4 times the total cost of the project). Considering a long-term analysis, from 2006 to 2016, we quantify a cumulative increase in GDP of US$ 87 billion (1.4 times the trend that would have been observed without the referendum and 15.8 times the cost of the project).

Putting our results in perspective, the literature shows that infrastructure investments have one of the largest multiplier effects (Bivens, 2014), but that there is also some variation in the multipliers that have been estimated so far in multiple studies. For infrastructure spending in the US, a GDP multiplier effect between 1.6 to 1.8 is reported by Bivens (2011). A more recent study by Leduc & Wilson (2013) reports a multiplier of 2 for highway investments in the US, but highlights the large heterogeneity observed in effects according to the time horizon used in the analysis. They obtain a short-term or impact multiplier of 3 and a long-run multiplier of 8 when considering six to eight years out. For the Panama case, the short-term multiplier effects we obtain for private investment (between 1 to 3 years after the announcement) are around 1.03, and the medium-term effects (5 years after the announcement) are around 1.8. These results mean that private investment catalyzed by the project is between 1.03 and 1.8 times the size of total canal investment or, alternatively, each US$1 invested in the Canal expansion project attracted between US$1.03 to US$1.8 of private investment in the short and medium term. For the GDP estimation, the overall multiplier is 16 for the period 2006 to 2016, the short-term multiplier is 2.1, and the medium-term multiplier is 4.4.

If we compare our results with the predictions provided by studies conducted prior to the Panama Canal expansion and based on Compytable General Equilibrium (CGE) models, we

[17] We convert results presented in US$ PPP values to US$ using the PPP exchange rate reported for Panama by WEO for 2007-2016. The total impacts are equal to US$81 PPP and total project investment in PPP values is US$9.3 billion PPP.

see that those studies projected an increase in GDP growth of 3.97% during the 8-year construction phase. Our results show that the average growth rate of GDP for Panama between 2006 and 2016 was 7.5% and that the growth rate for synthetic Panama was 3.8%. Therefore, the increase in the growth rate of GDP that can be attributed to the expansion project is 3.7%, which is quite close to the projections by Pagano *et al.* (2012). In terms of the impacts on private investment, the previous study did not take this into consideration during the construction period. Instead, the authors developed projections starting in 2015, the year after the expanded Canal was expected to start operations, predicting an increase in overall investment of 15%. Our results show a causal increase in private GFCF of 17.6% between 2006 and 2016. These results are larger than the projections, even though we do not consider the impacts after the project was completed and we only focus on private investment. This suggests that previous studies underestimated the response of the private sector.

Overall, our results highlight the importance of quantifying private sector catalyzation effects in the context of large infrastructure investments and the relevance of the private sector in driving economic activity and GDP growth. It is important to have in mind that results might vary across countries and types of infrastructure projects being evaluated. The Panama Canal project has proven to be quite unique, not only due to the large amount of finance involved, but also due to the strategic nature of the canal, both for Panama and the rest of the world. Given the limited availability of data for the post-expansion period (i.e. 2017-2018), we only estimate effects that occurred during the construction phase; however, the large effects obtained reinforce the importance of taking into account anticipation effects when evaluating infrastructure projects that may change country's expectations and private investors' beliefs. Finally, it is important to keep in mind that this study provides only a partial equilibrium view of the effects. Although we identify important increases in investment and economic activity, we do not conduct a distributional analysis or identify winners and losers that might have emerged as a result of project construction and operation. This type of analysis lies outside the scope of this work, but will need to be answered in future studies to provide a broader picture of the development impacts brought by the expansion of the Panama Canal.

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A Donor Countries

Table A1: Construction of donor pool

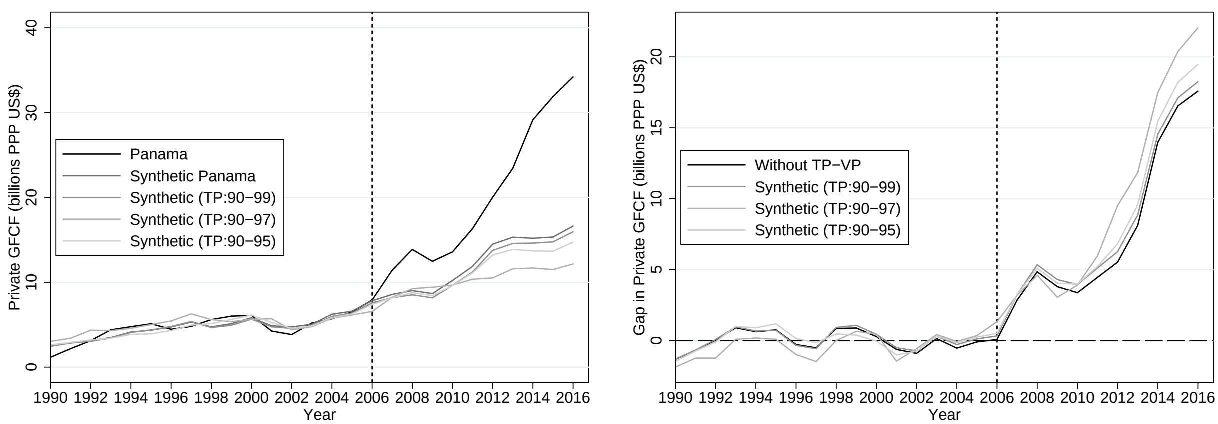
Country	Financial Centre	Port	Country	Financial Centre	Port
Europe & Central Asia			**Sub-Saharan Africa**		
Albania	0	0	Botswana	0	0
Armenia	0	0	Burundi	0	0
Azerbaijan	0	0	Cameroon	0	0
Bulgaria	0	0	Congo, Rep.	0	0
Moldova	0	0	Equatorial Guinea	0	0
Poland	1	0	Gabon	0	0
Romania	0	1	Gambia, The	0	0
Russian Federation	1	1	Kenya	0	0
Ukraine	0	1	Lesotho	0	0
			Mauritius	1	0
Latin America & Caribbean			Mozambique	0	0
Argentina	1	1	Namibia	0	0
Bahamas, The	1	0	Nigeria	0	0
Belize	0	0	Rwanda	0	0
Bolivia	0	0	Sierra Leone	0	0
Brazil	1	1	South Africa	1	1
Chile	0	1	Swaziland	0	0
Costa Rica	0	1	Tanzania	0	0
Dominican Republic	0	0	Uganda	0	0
Ecuador	0	1			
Haiti	0	0	**Middle East & North Africa**		
Honduras	0	0	Algeria	0	0
Mexico	1	1	Egypt, Arab Rep.	0	1
Panama	1	1	Lebanon	0	1
Paraguay	0	0	Morocco	0	0
Peru	0	1			
Trinidad and Tobago	0	0	**East Asia & Pacific**		
Uruguay	0	1	Malaysia	1	1
Venezuela, RB	0	1	Philippines	1	1
			Thailand	1	1
South Asia			Vietnam	0	1
Bangladesh	0	1			
India	1	1			
Sri Lanka	0	1			

Note: The table reports the list of countries that have at least 10 observations in the pre-treatment period (1990-2005) across the covariates used for the SCM analysis: public gross fixed capital formation, GDP per capita, population, trade openness, variations in the exchange rate, consumption, interest rate, and private gross fixed capital formation. We also highlight the countries that have ports or are considered financial centers and that are the ones in the donor pool.

B Additional Tables and Figures for private GFCF

A cross-validation technique is applied to check the sensitivity of the results to the selection of the v_m weights. To do this, we divide the pre-treatment period into a training and a validity period. Then, using predictors measured in the training period, we select the weights (v_m^*) such that the resulting synthetic control minimizes the root mean square prediction error (RMSPE)[18] over the validation period. Finally, with these weights (v_m^*) and the predictors observed in the validation period we estimate a synthetic Panama. Figures B1a and B1b present the original estimated result (without training and validity period) and three robustness checks with different definitions of the training (using 9, 7, and 5 years as the training period) and validation period. In all cases the results remain unchanged, despite having less pre-treatment information in some specifications.

Figure B1: Robustness Check - Cross-Validation to choose v_m weights

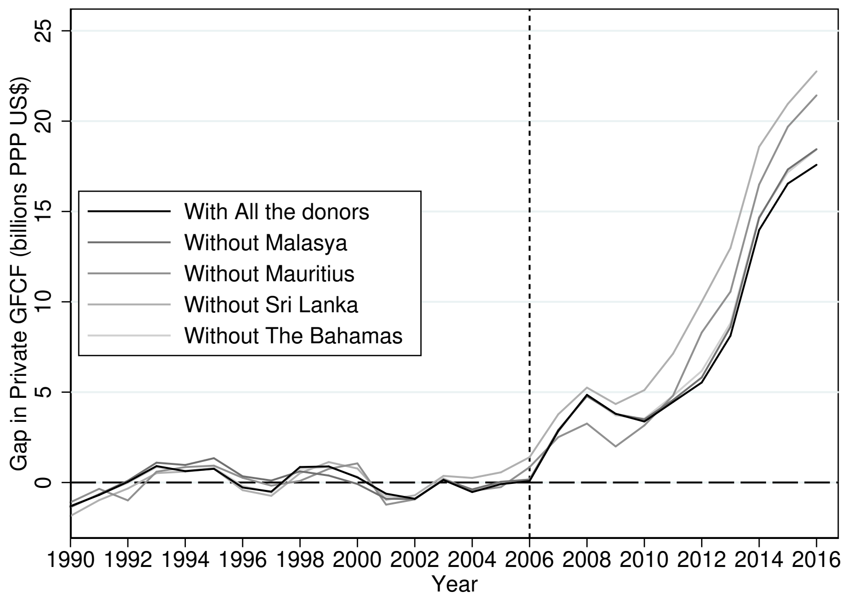


(a) Trends in Private GFCF (b) Gap in Private GFCF

Another robustness check used in the SCM literature is the Leave One Out Test that shows how sensitive results are to changes in the country weights or to data from a particular country (Abadie *et al.*, 2015). For this, we iteratively re-estimate the baseline model omitting in each iteration one of the countries that received a positive weight, as reported in Table 2. Figure B2 presents the estimated gaps in private GFCF for each specification and shows that, regardless of the country that is excluded, the main results are still observed.

[18] The RMSPE measures lack of fit between the path of the outcome variable for any particular country and its synthetic counterpart. The cross-validation technique is similar to minimizing out-of-sample prediction error.

Figure B2: Robustness Check - Leave One Out Test



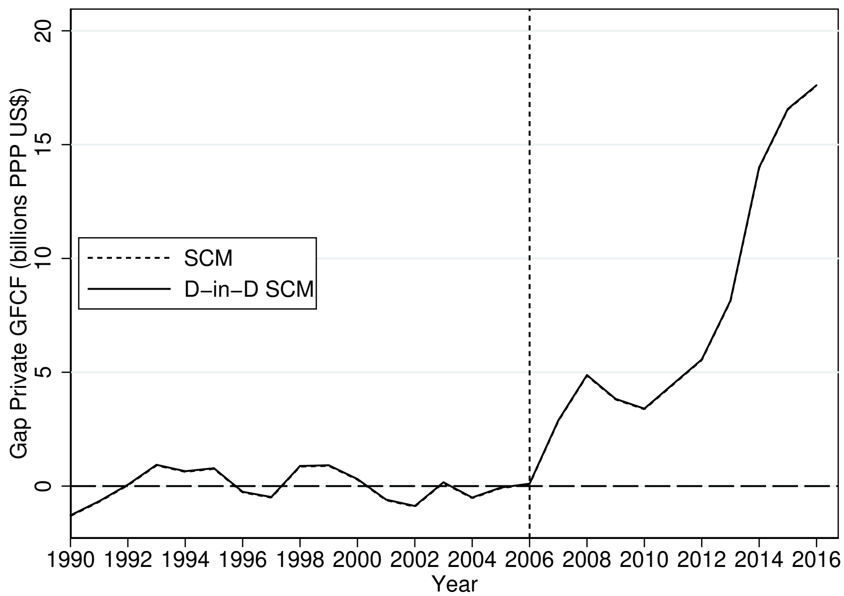
Even though the SCM chooses the optimal weights to minimize the pre-treatment MSPE between the treated unit and its synthetic counterpart, there might still be differences in levels in the pre-treatment period. To solve this potential problem, Garcia Lembergman *et al.* (2015) developed a Difference-in-Differences (DID) approach to subtract pre-treatment differences from post-treatment differences. Following this approach we can obtain the impact of the Canal expansion on private investment attraction as:

$$\widehat{\beta_{Pt}} = \left(Y_{Pt} - \sum_{j=1}^{J} w_j^* Y_{jt} \right) - \frac{1}{T_0} \sum_{t_0=0}^{T_0} \left(Y_{Pt_0} - \sum_{j=1}^{J} w_j^* Y_{jt_0} \right) \tag{4}$$

where $t \epsilon \{T_0 + 1, \ldots, T\}$. The first term of Equation (4) is the difference between Panama and its synthetic counterpart after the Canal expansion, and the second term is the same difference but averaged for the pre-treatment period. The second term of the equation approximates zero when the synthetic control unit adjusts better to private investment in Panama before the Canal expansion. Therefore, if the results are robust, the second term should be close to zero and the results should remain unchanged.

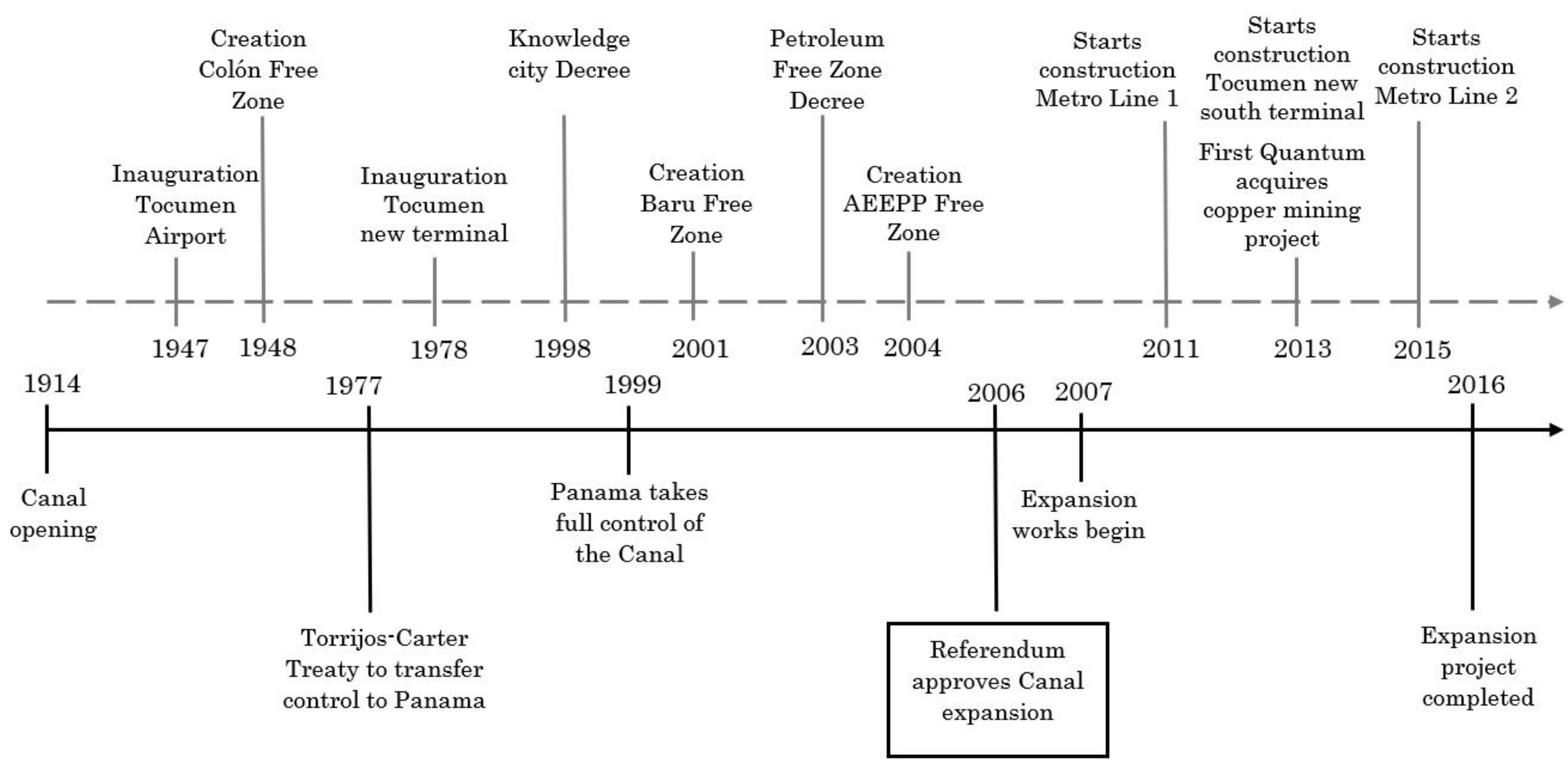
Figure B3 presents the estimated gaps in private GFCF for the traditional SCM (black dashed line) and for the DID (solid line), showing that our results are robust (remain unchanged) to the inclusion of this correction.

Figure B3: Robustness Check - Differences-in-Differences SCM



Finally, we explore whether other important events or investments happened in the country around the year 2006 and that could be confounded with the impacts of the Canal expansion announcement. In the upper panel of Figure B4, reported in the Appendix, we show the timeline of large events that happened in the country, inlcuding the creation of free zones and the beginning of the construction of the first metro line.

Figure B4: Timeline of events around announcement



C Additional tables and figures for GDP estimates

Figure C1: Evolution of Gross Domestic Product (GDP)
Panama and donor pool

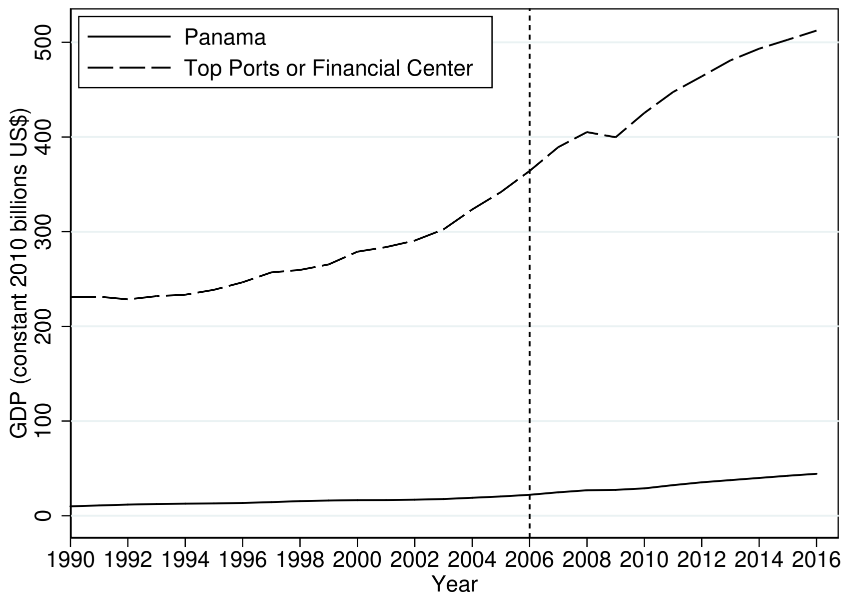


Table C1: Pre-Panama's Canal Expansion (1990-2005 average) − GDP

	Donors	Panama		V Matrix
		Actual	Synthetic	Weights
GDP (constant 2010 billions US$)	265.26	14.83	14.95	0.66
2005 GDP (constant 2010 billions US$)	341.83	20.36	19.97	0.08
GFCF (in billions 2010 PPP)	52.76	3.08	3.44	0.01
Exports (in billions 2010 US$)	59.71	9.61	7.46	0.00
Imports (in billions 2010 US$)	46.64	11.21	8.11	0.00
Government Expenditure (in billions 2010 US$)	44.86	2.24	2.19	0.11
Consumption (in billions 2010 US$)	149.06	9.64	9.62	0.08
Population (in millions)	84.58	2.89	2.84	0.04
Land Area (in thousand sq. km)	1,598.28	74.34	28.43	0.00
Agricultural Land (% of land area)	42.36	29.27	29.27	0.02
Unemployment (% of total labor force)	8.68	13.42	8.05	0.00

Figure C2: Place Placebo − GDP
(Post/Pre-Canal Expansion Announcement MSPE)

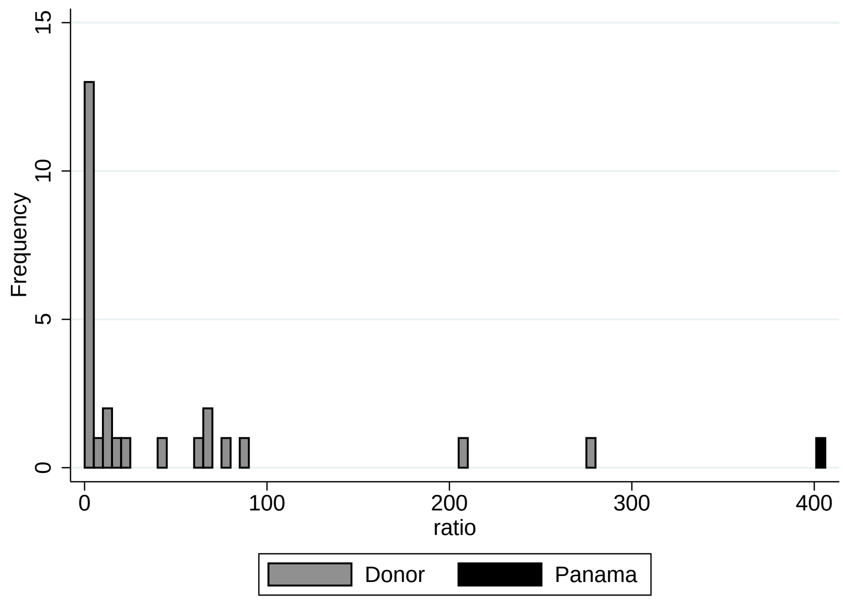
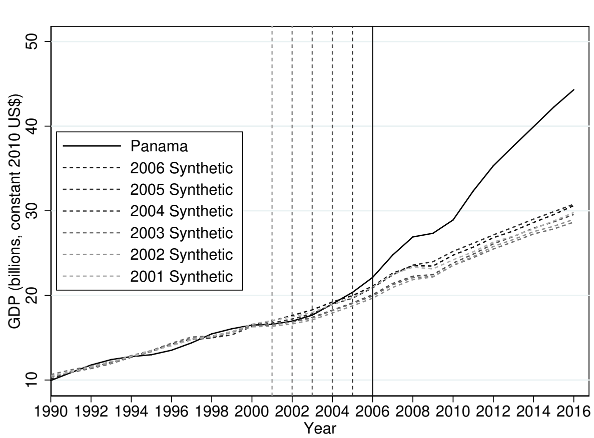
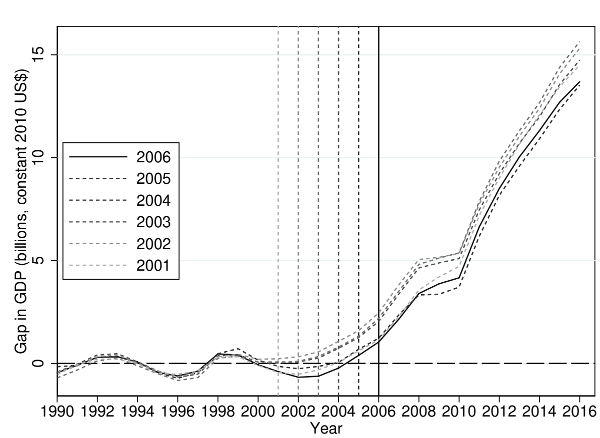


Figure C3: Time Placebo − GDP

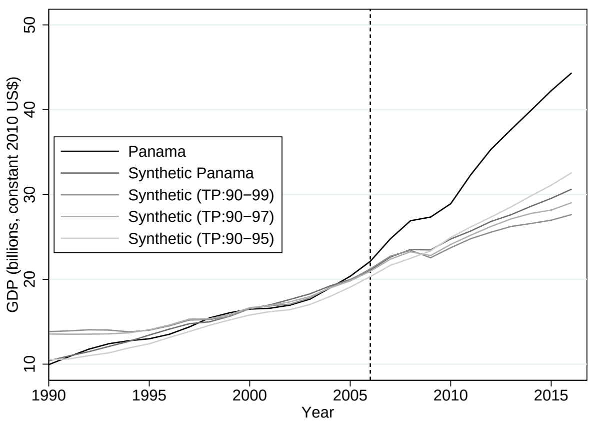


(a) Trends in GDP

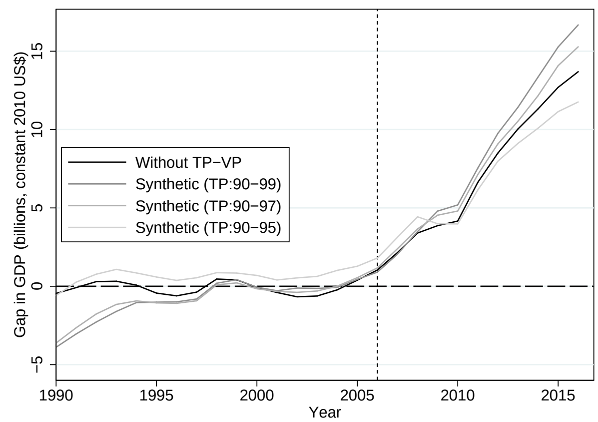


(b) Gap in GDP

Figure C4: Robustness Check - Cross-Validation to choose v_m weights $-$ GDP



(a) Trends in GDP



(b) Gap in GDP

Figure C5: Robustness Check - Leave One Out Test $-$ GDP