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Free Trade Zone of Manaus: An Impact Evaluation using the Synthetic Control Method*

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I apply the synthetic control method to Brazilian city-level data during the twentieth century in order to evaluate the economic impact of the Free Trade Zone of Manaus (FTZM). I find that this enterprise zone had significantly positive effects on real GDP per capita and Services Total Production per capita, but it also had significantly negative effects on Agriculture Total Production per capita. My results suggest that this subsidy policy achieved its goal of promoting regional economic growth at the cost of creating mis-allocation of resources among economic sectors. They also reject the view that an industrialization policy will benefit all economic sectors due to positive spill-overs from the manufacturing sector that are strong enough to compensate for the negative effect of the mis-allocation of resources.

Aplico o método do controle sintético para dados municipais brasileiros durante o Século 20 com o objetivo de avaliar o impacto econômico da Zona Franca de Manaus (ZFM). Encontro que essa zona econômica teve impactos positivos e significantes sobre PIB real e Produção Total de Serviços per capita, mas teve efeitos negativos e significantes sobre a Produção Total Agrícola per capita. Meus resultados sugerem que essa política de subsídios alcançou seu objetivo de promover crescimento econômico regional ao custo de provocar má alocação dos recursos entre os setores econômicos. Eles também rejeitam a visão de que uma política de industrialização irá beneficiar todos os setor econômicos devido às externalidades positivas do setor manufatureiro serem tão altas a ponto de compensarem os efeitos negativos da má alocação de recursos.

1. INTRODUCTION

The *Free Trade Zone of Manaus* (FTZM) is a controversial Brazilian subsidy policy.[1] This enterprise zone was created in 1967 by the military dictatorship that ruled Brazil from 1964 to 1985. This policy was intended to populate the Brazilian Amazon Area and to promote regional growth by giving incentives to the manufacturing sector to substitute imports. In particular, it reduced the tariffs to import inputs

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[1] Although the FTZM encompasses not only tax reductions, but also fiscal benefits and non-binding quantitative constraints for imported goods, we use the expressions *subsidy policy* and *subsidy* to denote this broad class of stimulating policies for brevity.

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for the production of industrial goods only in the area close to the city of Manaus, with the aim of increasing the local production of final goods and decrease its imports in the entire country. Although the details of the law that regulated the FTZM changed through the years, FTZM's essence remained unchanged: a heavy subsidy policy to the manufacturing sector in Manaus. Moreover, the service sector was indirectly subsidized through reduced import tariffs, because Manaus' retailers could sell imported goods for lower prices. As with many other local development policies of this period (e.g., the Trans-Amazonian Highway), the FTZM was a costly policy whose benefits are clear neither in academic nor public debate.

In order to fill this lacuna and deepen our understanding of FTZM's benefits, I estimate FTZM's causal effect on the Manaus's real GDP per capita, Agriculture Total Production per capita, Manufacture Total Production per capita and Services Total Production per capita. To do this, I estimate a synthetic control unit for Manaus, using only other cities in the Brazilian North Region as control units, to approximate the counterfactual, i.e., what would have happened if this enterprise zone had not been created. Intuitively, the synthetic control method constructs a synthetic control unit based on a weighted average of control regions that is as similar as possible to the treated region in terms of covariates and pre-treatment outcomes. This technique is especially useful when the parallel trends assumption of the differences-in-differences estimator seems too strong, because the Synthetic Control Unit is constructed to guarantee that it follows a similar pre-treatment trend to the one followed by the treated region. I conduct inference as explained by Abadie, Diamond, & Hainmueller (2010) and Abadie, Diamond, & Hainmueller (2015). I also implement two robustness checks to verify the validity of my results.

I find that the effects of the FTZM on Manaus' economy are ambiguous. There is no evidence of impact on its Manufacture Total Production per capita, suggesting that this subsidy policy failed to achieve its main goal. There is a significant at the 10%-level *negative* effect on Agriculture Total Production per capita, evidence that this subsidy policy distorted incentives, artificially reducing the primary sector due to mis-allocation of resources—an effect that was stronger than any possible positive externality of the manufacturing sector on the agriculture sector. There is also a significant at the 5%-level positive impact on Services Total Production per capita, which indicates that the main impact of the FTZM was due to lower import tariffs than those imposed in the rest of the country, attracting Brazilian tourists willing to buy imported goods at lower prices. Finally, the impact on real GDP per capita was positive and significant at the 10%-level, suggesting that this subsidy policy was successful in developing the city's economy.

My most important and direct contribution is an evaluation of a costly and historical investment decision in Brazil related to the import substitution industrialization policy. Considering that the relevance of the industrialization policy is still an open question for scholars and policy makers in Brazil, analyzing a historical and paradigmatic example of an import substitution industrialization policy is useful in guiding current economic policies. However, since FTZM's costs are hard to measure (particularly during the beginning of its implementation), I cannot state whether the significant benefits found surpass its costs or not.[2] This comparison is made even harder by the fact that a large amount of FTZM's costs are paid by other cities or states instead of Manaus.[3] This phenomenon allows me to tentatively conclude that FTZM is likely to pass a cost-benefit analysis when I consider only the city of Manaus, but I cannot draw any conclusion about its efficacy when I consider the entire country.

[2] Aggarwal (2012) points out that a real cost-benefit study of any *special economic zone*, such as FTZM, requires exhaustive data on numerous parameters that are extremely hard to collect rigorously. Castilho, Meneédez, & Sztulman (2015) argues that this type of study is even more challenging to implement in the case of FTZM due to a complex and evolving system of incentives and taxes.

[3] See Miranda (2013).

Furthermore, recent analyses of FTZM have focused on the twenty-first century and adopted descriptive evaluation tools as illustrated by Oliveira & Souza (2012), Sá & Machado (2012), Miranda (2013). Different from those works, I focus on the historical evolution of FTZM (twentieth century) and adopt causal inference tools,[4] allowing me to draw conclusions about FTZM's causal effects. Moreover, since Brazil had a smaller level of trade openness during the sixties, seventies and eighties than it had during the nineties or the beginning of the twenty-first century, the relative subsidy to the industrial and service sector in Manaus (when compared to other Brazilian cities) declined after Collor de Mello became president (1990). Consequently, more intense effects are expected during the period analyzed by me than during the period previously analyzed in the literature about the FTZM. Furthermore, my methodology and the conclusions that I have reached about this subsidy policy's effects also allow me to make a small and indirect contribution to the literature about mis-allocation of resources, since I provide evidence that FTZM distorted investment incentives among sectors. In particular, I conclude that FTZM achieved its goal of promoting regional economic growth at the cost of harming the Agriculture sector. Consequently, my results reject the view that an industrialization policy will benefit all economic sectors due to positive spill-overs from the manufacturing sector. More precisely, I find that the effect of mis-allocation of resources on the economy is stronger than the possible positive externalities generated by the manufacturing sector.

Literature Review

The literature about FTZM's costs and benefits is ambiguous. On one hand, Oliveira & Souza (2012), descriptively analyzing data for the beginning of the twenty-first century, conclude that FTZM's fiscal costs are lower than its socio-economic benefits. Although they argue that FTZM has increased Manaus' inequality, they nevertheless found that it has increased Manaus' GDP and Human Development Index. In particular, they stress that the reduced import tariffs for Manaus attracted a large number of Brazilian tourists willing to buy imported goods at lower prices, stimulating the services sector. On the other hand, Miranda (2013) also descriptively analyzes data for the beginning of the twenty-first century, but reaches completely different conclusions. He argues that FTZM's impact on the region's level of development is modest and that the jobs created by this subsidy policy are low quality positions. Consequently, those benefits do not surpass this policy's fiscal costs, even though he focuses only on federal fiscal costs since state and municipal fiscal costs are extremely hard to measure. Finally, he concludes that the maintenance of FTZM will impose permanent costs on the public sector.

Regarding the FTZM's main goal (i.e., to stimulate the industrial sector in the Amazon region), Sá & Machado (2012) find that the FTZM presents higher rates of value added than Brazil as a whole between 2006 and 2010. They arrieve at this result by descriptively analyzing data from 1996 to 2010. Another interesting economic effect caused by the FTZM is studied by Castilho et al. (2015). They apply micro-decomposition techniques and find that, while labor income was a major driver of poverty and inequality declines for the municipality of Manaus in the 2000–2010 decade, non-labor income was far more important in the rest of the state of Amazonas.

The international literature about other enterprise zones around the world is also ambiguous. On one hand, Ham, Swenson, Imrohoroglu, & Song (2011) and Busso, Gregory, & Kline (2013) present a positive perspective on this type of policy. Ham et al. (2011) analyze, in the United States of America (USA), the economic impact of State Enterprise Zones, Federal Empowerment Zones and Federal Enterprise Community programs. Using a differences-in-differences approach, they found positive and significant effects on the unemployment rate, the poverty rate, the fraction with wage and salary income and the

[4] The Synthetic Control Method was developed by Abadie & Gardeazabal (2003), Abadie et al. (2010) and Abadie et al. (2015) in order to address counterfactual questions involving only one treated unit as it is common in comparative case studies as the one analyzed in this article.

employment level and conclude that enterprise zones are effective in their goal of boosting local labor markets. Busso et al. (2013) also analyze the Federal Empowerment Zones program using a differences-in-differences estimator. They find that this policy substantially increased the local employment rate and wages without increases in the local population or cost of living. Consequently, they conclude that this policy's efficiency costs are relatively modest. On the other hand, Gobillon, Magnac, & Selod (2012) study a French enterprise zone policy and, using a combination of a hazard model, a matching estimator and a differences-in-differences method, find only a small short-run effect on the rate at which unemployed workers find a job. Based on this result, they conclude that this enterprise zone policy is likely to be cost-ineffective. A similar finding for the same enterprise zone policy is reached by Gobillon & Magnac (2016) using an interactive effect model.

The structure of this article is simple and straightforward. In section 2, I explain the institutions that govern the FTZM and discuss the possible theoretical effects of this subsidy policy. I summarize the synthetic control method in section 3 and describe the data used in this research in section 4. In section 5, I describe my main results and two robustness checks, and in section 6 I conclude.

2. INSTITUTIONAL DESCRIPTION

The enterprise zone FTZM was created in 28th February 1967 as a subsidy policy to promote regional growth by giving incentives to the manufacturing sector to substitute imports according to Decree Law n. 288. This policy reduced the tariffs to import inputs to produce industrial goods only in the area close to the city of Manaus, with the aim of increasing local production of final goods and decreasing its imports in the entire country. Although the details of the law that regulated the FTZM changed through the years, FTZM's essence remained unchanged: a large subsidy to the manufacturing sector in Manaus.[5] The service sector was indirectly subsidized through reduced import tariffs, because Manaus' retailers could sell imported goods for lower prices, attracting many Brazilian tourists as stressed by Oliveira & Souza (2012).

In more detail, the FTZM presented three phases during the years analyzed in this article.[6]

1. The first phase ran from 1967 to 1975 and consisted of a policy of large subsidies to the industrial and services sectors. In particular, some industrial goods could only be imported by retailers located in Manaus, being prohibited in the rest of the country. For this reason, Manaus received a huge influx of Brazilian tourist who were looking for cheap imported goods.

2. The second phase ran from 1975 to 1990 and consisted of a even larger subsidies to the industrial and services sectors. In particular, in order to receive the fiscal benefits associated with the FTZM, firms should not only be located in Manaus, but also abide by local content requirements, i.e., they should use at least a minimal percentage of national products as inputs.

3. The third phase ran from 1991 to 1996 and coincided with the opening of the Brazilian economy under presidents Collor de Mello (1990–1992), Itamar Franco (1992–1994) and Fernando Henrique Cardoso (1995–2002). Since import tariffs were reduced across the entire country, the relative subsidy received by firms located in Manaus (when compared to firms in other parts of the country) was reduced and the FTZM lost part of its relevance.

[5] See Oliveira & Souza (2012) and Miranda (2013) for details about the creation and implementation of FTZM. Machado, Junior, Costa, & Santana (2006) provides a critical historical overview about the FTZM.

[6] The information in this paragraph is a summary of SUFRAMA's website about the history of the FTZM: http://www.suframa.gov.br/zfm_historia.cfm (in Portuguese). SUFRAMA is the governmental agency responsible for supervising and implementing the FTZM.

Since FTZM is a subsidy policy to the Manufacturing and Services sectors in the city of Manaus, theory predicts that its GDP per capita level would increase in expense of other cities' income levels (mis-allocation among regions) and that its Manufacture Total Production per capita and Services Total Production per capita would increase at the expense of other sectors' production (mis-allocation among sectors).[7] Another possible explanation for an increase in Manaus' per capita GDP is that a stronger manufacturing sector generates positive spill-overs due to its working dynamics, increasing total production of all economic sectors.[8]

Intuitively, a sectoral subsidy such as the FTZM has two effects in opposite directions. On one hand, an increase in the subsidy increases the output of both sectors because it directly reduces the cost of production in the manufacturing sector, increasing its output and generating positive externalities to the agriculture sector. On the other hand, an increase in the subsidy stimulates the manufacturing firms to use more resources, forcing the agriculture firms to use less inputs and mis-allocating resources between sectors. In the end, the overall effect is ambiguous. If positive externalities are strong enough, agricultural production increases. If the mis-allocation of resources is too intense, agricultural output decreases.

I aim to empirically evaluate which effect is stronger in the particular case of the Free Trade Zone of Manaus by analyzing city-level data for economic variables during the twentieth century. Regardless of the theoretical reason behind FTZM's economic effects, it is important to note that its evolution during the twentieth century implies that its effect would increase from the first phase to the second phase and it would be smaller during the nineties.

3. SYNTHETIC CONTROL ESTIMATOR

The methodology applied in this case study was proposed in a series of three seminal articles by Abadie & Gardeazabal (2003), Abadie et al. (2010) and Abadie et al. (2015). Abadie et al. (2010) propose the following model to estimate the impact of a treatment when only one unit is treated.

Suppose that we observe data for $(J+1) \in \mathbb{N}$ units during $T \in \mathbf{N}$ time periods. Additionally, assume that there is a treatment that affects only unit 1 from period T_0+1 to period T uninterruptedly, where $1 \leq T_0 < T$ is a natural number. Let $Y^N_{j,t}$ be the potential outcome that would be observed for unit j in period t if there were no treatment for $j \in \{1,\dots,J+1\}$ and $t \in \{1,\dots,T\}$. Let $Y^I_{j,t}$ be the potential outcome that would be observed for unit j in period t if unit j received the treatment from period T_0+1 to T. Define

$$\alpha_{j,t} = Y^I_{j,t} - Y^N_{j,t} \tag{1}$$

as the treatment effect for unit j in period t and D_{jt} as a dummy variable that assumes a value of 1 if unit j receives the treatment in period t and 0 otherwise. With this notation, we have that the observed outcome for unit j in period t is given by

$$Y_{j,t} = Y^N_{j,t} + \alpha_{jt} D_{j,t}.$$

Since only the first unit receives the treatment from period T_0+1 to T, we have that:

$$D_{j,t} = \begin{cases} 1 & \text{if } j = 1 \text{ and } t > T_0, \\ 0 & \text{otherwise.} \end{cases}$$

[7] Hsieh & Klenow (2009) and Restuccia & Rogerson (2008) discuss the importance of misallocation of resources in explaining productivity differences.

[8] Cavalcanti, Mata, & Toscani (2016) argue that the Brazilian oil sector present positive spill-overs, because oil discoveries in Brazil have increased not only the manufacturing sector, but also the services sector.

We aim to estimate $\left(\alpha_{1,T_0+1},\ldots,\alpha_{1,T}\right)$. Since $Y^I_{1,t}$ is observable for $t > T_0$, equation (1) guarantees that we only need to estimate $Y^N_{1,t}$ to accomplish this goal. More importantly, note that the treatment effect can vary over time, i.e., I estimate one treatment effect for each period $t \in \{T_0+1,\ldots,T\}$. This flexibility is important because the FTZM has three different phases (see section 2) that are likely to present heterogeneous effects that can feasibly be estimated through the Synthetic Control Method as explained below.

Let $\mathbf{Y}_1 = \left[Y_{1,1},\ldots,Y_{1,T_0}\right]'$ be the vector of observed outcomes for unit 1 in the pre-treatment period and $\mathbf{X}_1$ a $(K\times 1)$-vector of predictors of $\mathbf{Y}_1$. Let $\mathbf{Y}_0$ be a $(T_0\times J)$-matrix, whose $(j-1)$-th column is given by $\mathbf{Y}_j = \left[Y_{j,1},\ldots,Y_{j,T_0}\right]'$ for each $j \in \{2,\ldots,J+1\}$, and $\mathbf{X}_0$ is a $(K\times J)$-matrix that contains the values of the same K predictors for the J control units.[9] Define the weighting vector $\mathbf{W} = \left[w_2\cdots w_{J+1}\right]'$ of $(J\times 1)$-dimension, where $w_j \geq 0$ for each $j \in \{2,\ldots,J+1\}$ and $\sum_{j=2}^{J+1} w_j = 1$. Intuitively, $\mathbf{W}$ measures the relative importance of each control unit in the synthetic control of unit 1. Additionally, define a positive semidefinite diagonal weighting matrix $\mathbf{V}$ of $(K\times K)$-dimension. Intuitively, $\mathbf{V}$ measures the relative importance of each one of the K predictors.

Since we want to make unit 1's synthetic control as similar as possible to the actual unit 1, we choose $\widehat{\mathbf{W}}(\mathbf{V})$ such that

$$\widehat{\mathbf{W}}(\mathbf{V}) \coloneqq \underset{\mathbf{W}\in\mathcal{W}}{\arg\min}\,(\mathbf{X}_1 - \mathbf{X}_0\mathbf{W})'\mathbf{V}(\mathbf{X}_1 - \mathbf{X}_0\mathbf{W}), \tag{2}$$

where $\mathcal{W} = \left\{\mathbf{W} = \left[w_2\cdots w_{J+1}\right]' \in \mathbb{R}^J \,:\, w_j \geq 0 \text{ for each } j \in \{2,\ldots,J+1\} \text{ and } \sum_{j=2}^{J+1} w_j = 1\right\}$.

The notation makes clear that the correspondence $\widehat{\mathbf{W}}(\mathbf{V})$ for problem (2) depends on $\mathbf{V}$. Abadie et al. (2010) propose using $\widehat{\mathbf{V}}$ such that

$$\widehat{\mathbf{V}} \coloneqq \underset{\mathbf{V}\in\mathcal{V}}{\arg\min}\left(\mathbf{Y}_1 - \mathbf{Y}_0\widehat{\mathbf{W}}(\mathbf{V})\right)'\left(\mathbf{Y}_1 - \mathbf{Y}_0\widehat{\mathbf{W}}(\mathbf{V})\right), \tag{3}$$

where $\mathcal{V}$ is the set of positive semidefinite diagonal matrices of dimension $(K\times K)$. Intuitively, this technique makes the synthetic control of unit 1 as similar as possible to the actual unit 1 during the pre-treatment period when we choose the Euclidian metric to evaluate the distance between the observed outcomes for unit 1 and the values predicted by the synthetic control.

With $\widehat{\mathbf{V}}$ chosen, the synthetic control weights of unit 1 are given by

$$\widehat{\mathbf{W}} \coloneqq \widehat{\mathbf{W}}(\widehat{\mathbf{V}}) = \left[\widehat{w}_2\cdots\widehat{w}_{J+1}\right]'.$$

For each $t \in \{T_0+1,\ldots,T\}$, the estimator of $Y^N_{1,t}$ according to the synthetic control method is given by

$$\widehat{Y}^N_{1,t} = \sum_{j=2}^{J+1}\widehat{w}_j Y_{j,t}.$$

Now, we can estimate the entire vector of treatment effects,

$$\widehat{\alpha}_{1,t} = Y_{1,t} - \widehat{Y}^N_{1,t},$$

for $t \in \{1,\ldots,T\}$. While the post-treatment gaps ($\widehat{\alpha}_{1,t} = Y_{1,t} - \widehat{Y}^N_{1,t}$ for $t \geq T_0+1$) are estimates of the parameters of interest (i.e., the causal effect of the FTZM on economic variables), we can use the pre-treatment gaps ($\widehat{\alpha}_{1,t} = Y_{1,t} - \widehat{Y}^N_{1,t}$ for $t \leq T_0$) as an indirect test of the validity of the synthetic

[9] Some lines of matrix $\mathbf{X}_1$ and $\mathbf{X}_0$ can be linear combinations of the variables in $\mathbf{Y}_1$ e $\mathbf{Y}_0$, while other lines can contain covariates that help to predict the outcome variable.

control estimator. Since the synthetic control unit should follow the counterfactual outcome $\left(Y_{1,t}^{N}\right)$ and we observe this potential outcome during the pre-treatment period, we expect the pre-treatment gaps to be close to zero.

In order to test the significance of the estimated effects, Abadie et al. (2010) and Abadie et al. (2015) propose the following inference procedure.[10] In order to determine how unlikely the estimator $\widehat{\alpha}_{1,t} = Y_{1,t} - \widehat{Y}_{1,t}^{N}$ for $t \geq T_0 + 1$ under the null of no effect is, Abadie et al. (2010) propose running placebo tests: assume that each control unit $j \in \{2,...,J+1\}$ had received the treatment, estimate its synthetic counterfactual and compare the $\widehat{\alpha}_{1,t}$ with $\widehat{\alpha}_{j,t}$ for each $t \geq T_0 + 1$ and $j \in \{2,...,J+1\}$. If $|\widehat{\alpha}_{1,t}|$ is abnormally large, there is evidence in favor of rejecting the null hypothesis.

One drawback of the last method is that $|\widehat{\alpha}_{1,t}|$ can be abnormally large for some time periods, but not for others, implying that there is no clear rejection rule. This is a severe problem for any inference procedure, as pointed out by White (2000). In order to handle this issue, Abadie et al. (2015) propose a method for condensing information from all periods to conduct inference: estimate

$$RMSPE_j := \frac{\sum_{t=T_0+1}^{T}\left(Y_{j,t} - \widehat{Y}_{j,t}^{N}\right)^2 \Big/ (T - T_0)}{\sum_{t=1}^{T_0}\left(Y_{j,t} - \widehat{Y}_{j,t}^{N}\right)^2 / T_0} \tag{4}$$

for each $j \in \{1,\ldots,J+1\}$, compute

$$p := \frac{\sum_{j=1}^{J+1} \mathbb{1}\left[RMSPE_j \geq RMSPE_1\right]}{J+1}$$

and reject the null of no effect whatsoever if p is less than some pre-specified significance level.

Methodologically, synthetic control estimator's main competitor is the differences-in-differences estimator. The latter option was previously applied to the estimation of enterprise zones' economic impact as my brief review of the literature makes clear. However, applying it to the dataset used in this analysis would be problematic, since its inference procedure requires a large number of treated and control units and the comparison group of this work is relatively small.[11] Moreover, this methodology restricts the treatment effect to be constant during the post-treatment period, a very strong assumption in the FTZM's context since the post-treatment period lasts for almost half a century and the treatment effects are likely to vary during the different phases of the FTZM.

These two issues are successfully tackled by the synthetic control method. First of all, its inference procedure is completely appropriate for a small sample such as ours.[12] Moreover and most importantly, this method allows me to estimate a completely flexible treatment effect as a function of time.

4. DATA DESCRIPTION

I collect data on GDP per capita, Agriculture, Manufacture and Services Total Production per capita in real values (Reais of 2000), Agriculture, Manufacture, Services and Government Production as shares of GDP, and Population Density for 49 Minimum Comparable Areas (MCAs)[13] in the Brazilian North

[10] For a generalization of this methodology, see Firpo & Possebom (2016).

[11] Even if I applied the inference procedure developed by Conley & Taber (2011), I would still need a large number of control units. However, Conley & Taber (2011) present a Monte Carlo experiment that shows that their inference procedure works for datasets with only 50 observed units. For this reason, I apply their technique as a robustness check for my main results.

[12] For more information about its inference procedure, see Firpo & Possebom (2016).

[13] Since many cities were divided or created during the twentieth century in Brazil, I can not use current cities as the unit of observation. For this reason, I use MCAs 1920 that capture the local economic units that would exist if cities remained stable during the last century.

Region for the years of 1920, 1939, 1949, 1959, 1970, 1975, 1980, 1985, 1996 and 1999.[14] I define the pre-treatment period as 1920–1959 and the treated region is MCA 1920 #2097002; this includes the current cities of Manaus, Anamã, Anori, Apuí, Autazes, Barreirinha, Beruri, Boa Vista do Ramos, Borba, Caapiranga, Careiro, Careiro da Várzea, Codajás, Iranduba, Itacoatiara, Itapiranga, Manacapuru, Manaquiri, Manicoré, Maués, Nova Olinda do Norte, Novo Airão, Novo Aripuanã, Presidente Figueiredo, Rio Preto da Eva, São Sebastião do Uatumã, Silves, Urucará, Urucurituba. Although the real unit of analysis (MCA 1920 #2097002) is larger than the current city of Manaus, I refer to it simply as *Manaus* for brevity. Finally, I apply the methodology proposed by Abadie & Gardeazabal (2003), Abadie et al. (2010) and Abadie et al. (2015) to construct a synthetic control unit of Manaus for each outcome variable (GDP per capita, Agriculture Total Production per capita, Manufacture Total Production per capita and Services Total Production per capita), using their own pre-treatment mean values, sectoral GDP shares, government size and population density as predictors.[15]

The chosen control group was not the only available option. I use all the MCAs in the Brazilian North Region because this region presents many characteristics that make it very different from other Brazilian regions. First of all, the Amazon Region almost coincides with the North Region, implying that the latter presents an unique environment and, as a consequence, faces very different economic challenges. Moreover, during the military dictatorship (1964–1985), the federal government implemented many policies whose main goal was to occupy and develop the North Region (e.g. the Trans-Amazon Road), implying that the cities in the North Region faced economic policies and shocks that were different from the ones faced by other Brazilian cities. Finally, since the North Region was the last one to be occupied, it is culturally different from the other regions, presenting, for example, a much larger Native Brazilian population share. For all these reasons, cities in the North Region are more comparable among themselves than other Brazilian municipalities, making the former group my preferred control group. As a robustness check, I raise another possible control group: the capital cities located in the North, Northeast and Midwest.

Table 1 reports the pre-treatment means of outcome and predictor variables for Manaus (column (1)) and the four synthetic versions of Manaus (columns (2)–(5)). Observe that the four synthetic control regions are very similar to the true Manaus regarding pre-treatment average values for the outcome variables and for the covariates. The only exceptions are the average values for *population density* and *Manufacture Total Production per capita* and some of the outcome variables that are not forced to match by the synthetic control method (e.g.: the Agriculture Total Production per capita for the synthetic control unit that fits the Manufacture Total Production).

Since Manaus is one of the least densely populated cities in the Brazilian North region, it is extremely hard for the synthetic control method to fit this predictor variable. Consequently, this methodology imposes a weight close to zero for this variable when constructing the synthetic units for all the outcome variables except Agriculture Total Production per capita.[16]

Since Manaus has the largest Manufacture Total Production per capita in the Brazilian North region, it is very hard for the synthetic control method to fit this outcome variable. Despite this, the synthetic control versions closely match Manaus for this variable even though it assigns a weight of only 13.7% to it when fitting GDP per capita.

Table 1 also reports the sample average (excluding Manaus) of those variables for each one of the samples (columns (6)–(9)). As expected, the synthetic units reproduce the values for the city of Manaus more precisely than a simple average even for most of the outcome variables that are not

[14] Due to missing data, I have information about 46 MCAs for Agriculture Total Production per capita, 22 MCAs for Manufacture Total Production per capita and 40 MCAs for Services Total Production per capita.

[15] More explicitly, matrix $\mathbf{X}_1$ contains pre-treatment average values of $\mathbf{Y}_1$, of sector GDP shares, of government size and of population density for each outcome variable.

[16] In order to save space, we do not report all weights $\widehat{\mathbf{W}}$ and $\widehat{\mathbf{V}}$ for each outcome variable. They are available upon request.

Table 1. Descriptive statistics (pre-treatment average values).

Variable	Manaus (1)	Synthetic Manaus GDP pc (2)	Synthetic Manaus ATP pc (3)	Synthetic Manaus MTP pc (4)	Synthetic Manaus STP pc (5)	Sample Average GDP pc (6)	Sample Average ATP pc (7)	Sample Average MTP pc (8)	Sample Average STP pc (9)
GDP pc (R$ of 2000)	1213.64	1213.49	+769.22	+1121.33	+981.49	470.96	476.74	513.85	488.76
ATP pc (R$ of 2000)	193.56	+107.45	191.01	+96.80	+90.30	245.77	248.43	204.08	237.48
MTP pc (R$ of 2000)	349.35	+330.89	+92.35	279.71	+229.19	56.64	57.49	63.87	63.36
STP pc (R$ of 2000)	670.74	+803.16	+488.48	+744.84	670.58	181.97	183.79	248.26	196.34
Population Density (Inhabitants per sq km)	0.60	32.96	0.73	36.57	24.02	3.76	3.49	5.46	4.35
Agriculture Share (%)	18.3	18.4	27.0	19.1	18.4	57.8	57.9	46.6	55.0
Manufacture Share (%)	22.6	21.3	16.6	22.5	22.7	9.6	9.5	11.1	8.9
Services Share (%)	59.0	61.3	56.9	58.3	59.1	35.6	35.3	42.7	37.3
Government Size (%)	9.5	9.9	9.8	10.1	9.7	6.7	6.4	7.5	7.1
Sample Size						49	46	22	40

Notes: XTP pc and *X Share* stand for *Sector X Total Production per capita* and *Sector X Production as a share of GDP*, respectively. Since, for each outcome variable, I estimate a different Synthetic Unit using a different sample, I report descriptive statistics for each one of the four synthetic units and each one of the four samples. I name each synthetic region and each sample according to their associated outcome variable. The different sample sizes are due to missing data. In columns (2)–(5), cells marked with a + indicates that the synthetic control method is not forced to match the indicated variable.

forced to match by the synthetic control method (e.g. GDP per capita for the synthetic control unit that fits the Manufacture Total Production per capita). This suggests that the synthetic control estimator is an better option than simpler methods for this case study.

5. RESULTS

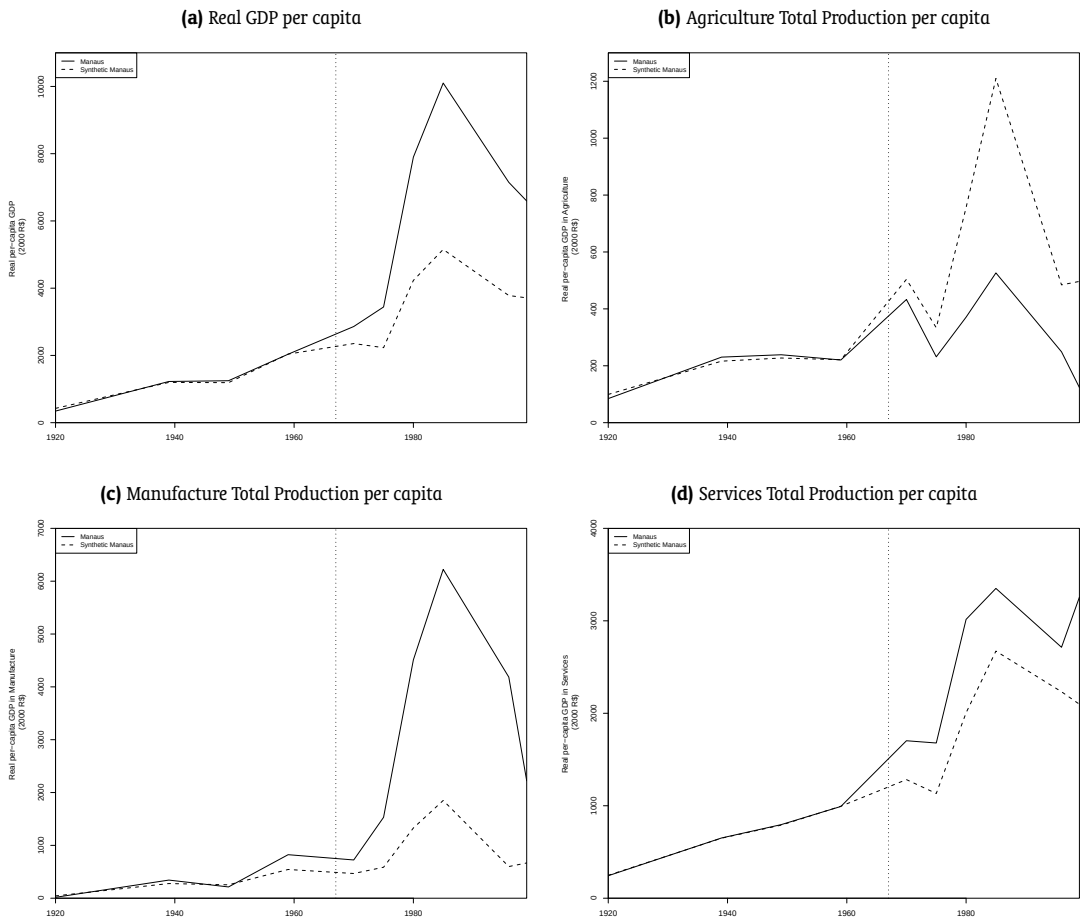
Figure 1 plots the time series for Manaus and its synthetic control versions for the variables real GDP per capita (subfigure 1(a)), Agriculture Total Production per capita (subfigure 1(b)), Manufacture Total Production per capita (subfigure 1(c)) and Services Total Production per capita (subfigure 1(d)). As those graphs show, FTZM seems to have had a positive effect on real GDP per capital, Manufacture Total Production per capita and Services Total Production per capita, and a negative impact on Agriculture Total Production per capita. These results support the view that the effect of the mis-allocation of resources are stronger than the effect of possible positive externalities as I discussed in the section 2 since we observe a negative effect for one of Manaus' economic sectors. Moreover, as it is easy to see, those point estimates suggest that FTZM has had a very large economic impact.

Regarding the magnitude of the estimated effects, note that FTZM's economic impact is relevant. For the last observed year (1999), FTZM's estimated effect on GDP per capita is R$2880, while Manaus' real GDP per capita is R$6593, implying the FTZM's impact represents 44% of the realized outcome. Given the complexity and the size of this subsidy policy, such a large impact is expected. Moreover, for 1999, Manaus's counterfactual Agriculture Total Production per capita would be three times larger than its realized value, while FTZM's contribution to Manufacture and Services Total Production per capita represents 70% and 36% of the realized outcome, respectively.

Figure 1 also allow us to indirectly verify the validity of the synthetic control method. By looking at the pre-treatment fit, we see that all the synthetic regions closely follow Manaus' trend. This behavior suggests that the synthetic control method can properly approximate the counterfactual outcome and, thus, estimate the treatment effect.

Now, consider only the black lines on subfigures 2(a), 2(b), 2(c) and 2(d). They show FTZM's estimated economic impact, since they represent the differences between the black and the dotted lines

Figure 1. Estimated effects using the Synthetic Control Method.

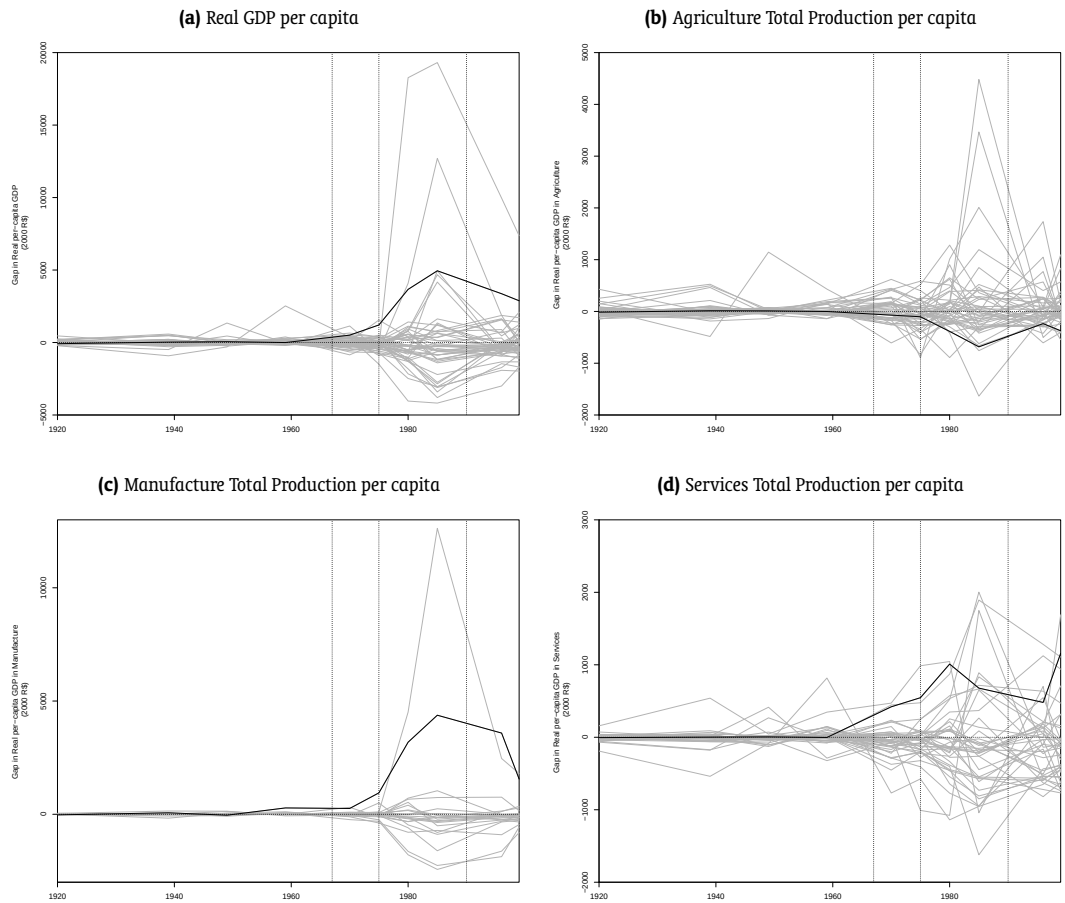


Note: The vertical dotted line indicates the beginning of the treatment period (1967).

on subfigures 1(a), 1(b), 1(c) and 1(d). As one can see, FTZM's effect on GDP per capita and Agriculture and Manufacture Total Production per capita has a parabolic shape, while its impact on Services Total Production per capital increases at the beginning of the post-treatment period and then stabilizes. These results illustrates the importance of using the Synthetic Control Method instead of the differences-in-differences estimator, since the former allows me to estimate time-varying treatment effects. More importantly, the parabolic shape of the effects agree with our expectations given that the relative subsidy associated with the FTZM was stronger in the second phase than it was in the first or the third phase. Note that the estimated effects for all outcome variables are initially weak during the first phase and get much stronger during the second phase, weakening again after the third phase. (The vertical dotted lines in Figure 2 indicates the beginning of each phase.)

So far, I have only presented point estimates and have not discussed the statistical significance of my results. To address this, I follow Abadie et al. (2010) and plot placebo tests for each analyzed variable (see the gray lines in Figure 2). Looking at subfigures 2(a), 2(b), 2(c) and 2(d), it seems that FTZM had a significant impact only on Manaus' real GDP per capita and Manufacture Total Production per capita.

Figure 2. Placebo tests.



Note: While the gray lines show the estimated placebo effect for each outcome variable and for each control city, the black lines show the estimated impact of FTZM on Manaus' economy for each outcome variable. The first vertical dotted line indicates the beginning of the treatment period (1967), while the second vertical dotted line indicates the beginning of FTZM's second phase (1975). Finally, the third vertical dotted line indicates the beginning of FTZM's third phase (1990).

However, this impression is contradicted when I apply the formal inference procedure described by Abadie et al. (2015) and use the RMSPE as a test statistic.[17]

I find that FTZM's economic effect has a p-value of 6.12% for real GDP per capita, 6.52% for Agriculture Total Production per capita, 63.64% for Manufacture Total Production per capita and 2.50% for Services Total Production per capita. The lack of significance for the results regarding the manufacturing sector suggests that this policy failed to achieve its main goal. However, the three significant results suggest that the positive effects on the service sector were more than enough to compensate for the negative impacts on the agricultural sector, implying that FTZM had a positive effect on Manaus' economy as a whole.

These findings allow me to conclude that FTZM is likely to pass a cost-benefit analysis when I consider only the city of Manaus. Although tentative, this conclusion is likely to be valid because most

[17] Firpo & Possebom (2016) discuss this inference procedure, formalizing and generalizing it.

of FTZM's costs were paid by cities outside the Amazon region. However, I cannot draw any conclusion about FTZM's efficacy when I consider the entire country without collecting data about its fiscal costs during the twentieth century. Another factor that complicates a cost-benefit analysis is that part of the FTZM's positive impacts on Manaus' real GDP per capita may be due simply to mis-allocation of resources among cities in the North Region, i.e., investments that would have been made in the control cities were made in Manaus due to FTZM. If this is the case, FTZM's effect for the country as a whole may be negative. I stress that this concern is addressed in the robustness checks subsection, where using another control group in order to construct the synthetic control unit reaches a similar result to the one present here, suggesting that the mis-allocation of resources among cities does not bias my results.

Furthermore, these results provide evidence in favor of rejecting the theory that the manufacturing sector in Manaus create positive spill-overs large enough to benefit all economic sectors, surpassing the detrimental effects of resources mis-allocation. If this were the case, I would find a positive impact of FTZM on Agriculture Total Production per capita. Actually, I find the opposite result in accordance with the theory of mis-allocation among sectors. For this reason, I conclude that FTZM achieved its goal of promoting regional economic growth at the cost of provoking mis-allocation of resources among sectors.

Robustness Checks

As a first robustness check, I run a standard differences-in-differences regression

$$y_{it} = \theta D_{it} + \mathbf{x}_{it}\beta + \alpha_i + \delta_t + \varepsilon_{it} \tag{5}$$

where i and t respectively index minimum comparable areas and time periods; y_{it} represents real GDP per capita or Sectoral Total Production per capita levels; D_{it} is a dummy variable that assumes the value of 1 only for Manaus during the post-treatment period; $\mathbf{x}_{it}$ is a row vector of control variables that contains Agriculture, Manufacture, Services and Government Production as shares of GDP, and Population Density; α_i is a city fixed effect, δ_t is a time fixed effect and ε_{it} is a error term. Moreover, I estimate a 90%-confidence interval for the coefficient of interest, θ, using the procedure proposed by Conley & Taber (2011), that is adequate when we observe a small number of treated units and a large number of control units.

Table 2 reports the estimated results for model (5) using the inference method suggested by Conley & Taber (2011). Regarding the point estimates, the magnitudes of the coefficient of interest for each dependent variable are similar to the average estimated effects of the synthetic control method for each analyzed outcome, illustrating the robustness of my findings. I also note that the confidence

Table 2. Differences-in-Differences results.

	Dependent Variable			
	GDP pc (1)	ATP pc (2)	MTP pc (3)	STP pc (4)
Point Estimate ($\hat{\theta}$)	2050	−532	1276	1066
Confidence Intervals	[−265, 3265]	[−809, −289]	[419, 1798]	[−106, 1606]
Sample Size	49	46	22	40

Notes: XTP pc stands for *Sector X Total Production per capita*. I report point estimates for the coefficient of interest, θ, in model (5) and its 90%-confidence interval based on the inference procedure proposed by Conley & Taber (2011). The different sample sizes are due to missing data.

intervals for the variables real GDP per capita, Manufacture Total Production per capita and Services Total Production per capita are extremely wide, indicating that the estimates are imprecise even if they are statistically significant as it is the case for the coefficient associated with the dependent variable Manufacture Total Production per capita. The only coefficient that is precisely estimated is the one associated with the dependent variable Agriculture Total Production per capita. In this case, the point estimate is negative and statistically significant, in accordance with the Synthetic Control results. Hence, my conclusions are robust to the choice of estimation method. Note also that the results of the differences-in-differences models also contradicts the positive spill-overs view, providing support for the mis-allocation predictions.

As a second robustness check, I change the control group. In the main results, the synthetic control unit is a linear combination of all the minimum comparable areas of the North Region because those localities are, culturally and environmentally, the most similar ones to Manaus. However, it is possible to think that the spatial proximity between Manaus and the control areas may bias the results for, at least, two different reasons: (i) if Manaus' growth stimulates its neighbors' economy due to positive spatial externalities, the main results are biased downwardly; and (ii) if investments that would have been done in cities close to Manaus were reallocated to Manaus due to FTZM's subsidies (mis-allocation of resources among cities), the main results are biased upwardly.

In order to address those concerns, I use a different control group: all the capital cities in the North, Northeast and Midwest regions. I choose those cities because their states are the poorest ones in Brazil, making them more comparable, and because they are located far away from Manaus, mitigating any spatial effect. I stress that, although there are currently 19 capital cities in those regions, we only observe 17 MCA since Rio Branco, Campo Grande and Cuiabá are aggregated in only one MCA.

Subfigures 3(a), 3(b), 3(c) and 3(d) present the estimated treatment effect and the placebo effects for this control group for each outcome variable of interest. Although the sample size is too small to detect any significant effects at the 5%-level,[18] the magnitude and shape of the estimated effects are very similar to the magnitude and shape of the main results as the comparison between figures 2 and 3 shows. Consequently, the main results and conclusions are robust to the choice of the control group and not simply generated by spatial contamination.

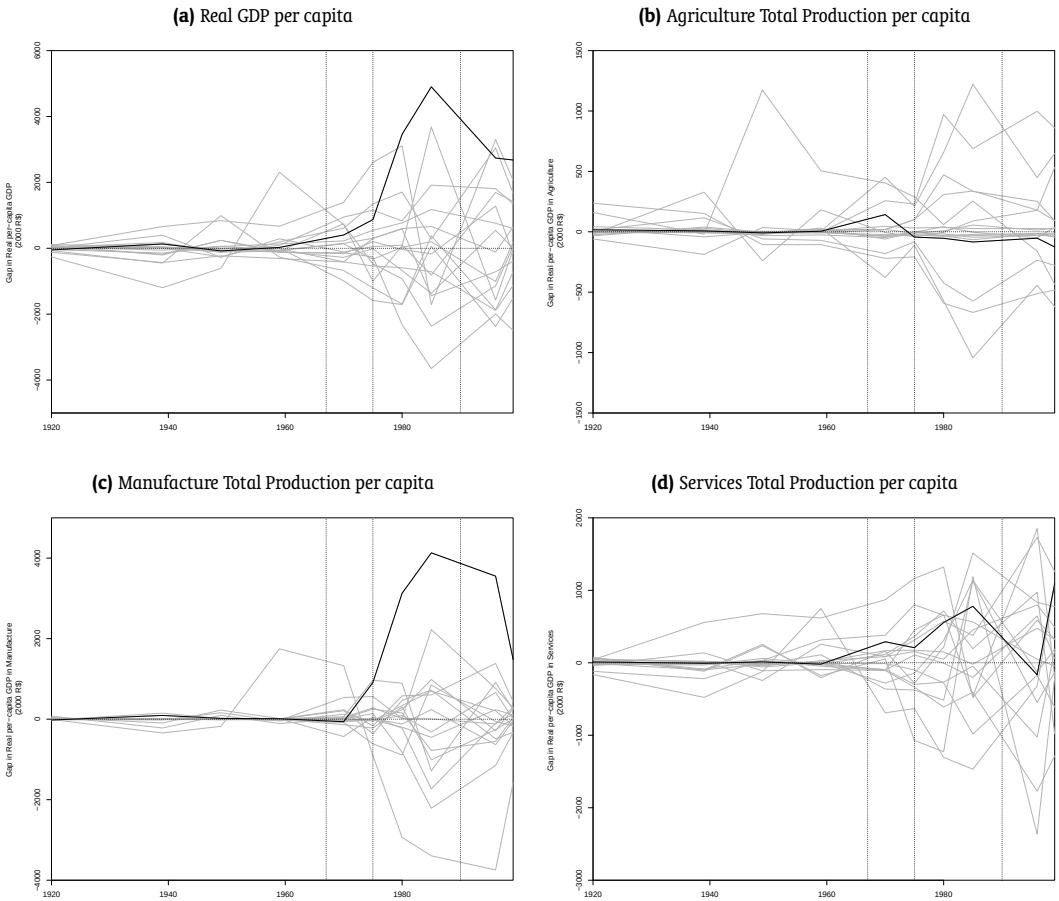
6. CONCLUSION

Applying the Synthetic Control Method to city-level data for cities of the Brazilian North region during the twentieth century, I evaluate the economic impact of the Free Trade Zone of Manaus. While FTZM's impact on Manaus' Manufacture Total Production per capita is non significant, its effect on the agriculture sector and the services sector are significant and present different signs—negative for the former and positive for the latter. At the end, FTZM's positive and significant effect on Manaus' real GDP per capita suggests that its positive impacts were larger than the negative ones, implying that this subsidy policy achieved its goal of promoting regional economic growth. Moreover, the time pattern of those effects during the twentieth century is expected considering the intensity of the FTZM's subsidies. When the relative subsidy associated to the FTZM (when compared to other Brazilian cities) is larger (second phase: 1975–1990), the estimated effects are also larger for all outcome variables.

Although it is possible to think that FTZM would pass a cost-benefit analysis when I consider only the city of Manaus, I do not have enough information to draw any conclusion about the relative magnitude of its costs and benefits when I consider Brazil as a whole. This tentative conclusion is due to the fact that a large amount of FTZM's costs is paid not by Manaus, but by cities outside the Amazon region.

[18] The treatment effects present p-values of 11.1%, 27.8%, 16.7% and 5.6% for the variables real GDP per capita, Agriculture Total Production per capita, Manufacture Total Production per capita and Services Total Production per capita, respectively.

Figure 3. Placebo tests using capital cities in poor states in the Donor Pool.



Note: While the gray lines show the estimated placebo effect for each outcome variable and for each control city, the black lines show the estimated impact of FTZM on Manaus' economy for each outcome variable. The first vertical dotted line indicates the beginning of the treatment period (1967), while the second vertical dotted line indicates the beginning of FTZM's second phase (1975). Finally, the third vertical dotted line indicates the beginning of FTZM's third phase (1990).

Moreover, my methodology does allow me to disentangle whether the positive impact on Manaus' real GDP per capita is due to positive spillovers that benefit all the city economic sectors and the entire country or due to mis-allocation of resources that harms Brazil as a whole. Since the positive spill-overs view predicts a positive impact of the FTZM on Agriculture Total Production per capita, my results contradicts this theory. In reality, my estimated negative impact on the agriculture sector is in accordance to the view that states that the detrimental effects of mis-allocated resources are strong enough to jeopardize any possible positive spill-over from the manufacturing sector.

REFERENCES

Abadie, A., Diamond, A., & Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's Tobacco Control Program. *Journal of the American Statiscal Association*, *105*(490), 493–505.

Abadie, A., Diamond, A., & Hainmueller, J. (2015). Comparative politics and the synthetic control method. *American Journal of Political Science*, *59*(2), 495–510.

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the Basque Country. *American Economic Review*, *93*(1), 113–132.

Aggarwal, A. (2012). *Social and economic impact of SEZs in India*. Oxford University Press.

Busso, M., Gregory, J., & Kline, P. (2013). Assessing the incidence and efficiency of a proeminent place based policy. *American Economic Review*, *103*(2), 897–947.

Castilho, M., Meneédez, M., & Sztulman, A. (2015, December 17). *Poverty and inequality dynamics in Manaus: Legacy of a free trade zone?* (G-MonD Working Paper No. 43). Retrieved from https://halshs.archives-ouvertes.fr/halshs-01245394

Cavalcanti, T., Mata, D. D., & Toscani, F. (2016, March). *Winning the oil lottery: The impact of natural resource extraction on growth* (IMF Working Paper No. 16/61). International Monetary Fund. Retrieved from http://www.imf.org/en/Publications/WP/Issues/2016/12/31/Winning-the-Oil-Lottery-The-Impact-of-Natural-Resource-Extraction-on-Growth-43789

Conley, T. G., & Taber, C. R. (2011). Inference with difference-in-differences with a small number of policy changes. *The Review of Economics and Statistics*, *93*(1), 113–125.

Firpo, S., & Possebom, V. (2016, March). *Synthetic control estimator: A generalized inference procedure and confidence sets.* Retrieved from https://goo.gl/t7QW8K

Gobillon, L., & Magnac, T. (2016). Regional policy evaluation: Interative fixed effects and synthetic controls. *Review of Economics and Statistics*, *(Forthcoming)*.

Gobillon, L., Magnac, T., & Selod, H. (2012). Do unemployed workers benefit from enterprise zones? The French experience. *Journal of Public Economics*, *96*, 881–892.

Ham, J. C., Swenson, C., Imrohoroglu, A., & Song, H. (2011). Government programs can improve local labor markets: Evidence from state enterprise zones, federal emporwement zones and federal enterprise community. *Journal of Public Economics*, *95*, 779–797.

Hsieh, C.-T., & Klenow, P. (2009). Misallocation and manufacturing TFP in China and India. *The Quarterly Journal of Economics*, *124*(4), 1403–1448.

Machado, J. A. C., Junior, A. R. O., Costa, F. A., & Santana, A. C. (2006). Metamorfoses do Modelo Zona Franca de Manaus: Desafios a Pesquisa e ao Planejamento do Desenvolvimento Regional. In E. Scherer & J. A. de Oliveira (Eds.), *Amazônia: Políticas públicas e diversidade cultural* (Vol. 1, p. 39-59). Rio de Janeiro: Garamond.

Miranda, R. N. d. (2013, Abril). *Zona Franca de Manaus: Desafios e vulnerabilidades* (Texto para Discussão No. 126). Brasília, DF: Núcleo de Estudos e Pesquisas do Senado Federal. Retrieved from http://goo.gl/Hj9NH0

Oliveira, J. L. d. C., & Souza, R. B. d. L. d. (2012). Um estudo sobre a renúncia tributária dos entes federativos e os benefícios gerados pela Zona Franca de Manaus. *Revista Estudos do CEPE*(36), 38–60.

Restuccia, D., & Rogerson, R. (2008). Policy distortions and aggregate productivity with heterogenous establishments. *Review of Economic Dynamics*, *11*, 707–720.

Sá, M. T. d. V., & Machado, J. A. d. C. (2012). *Polo Industrial de Manaus (PIM): A medida de seu valor adicionado comparado ao resto do Brasil.* Retrieved from http://goo.gl/2LwSjF

White, H. (2000). A reality check for data snooping. *Econometrica*, *68*(5), 1097–1126. doi: 10.1111/1468-0262.00152