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When Prices Go Awry

THE EFFECTS OF AN OIL PRICE BUST IN A SUBNATIONAL OIL-PRODUCING ECONOMY

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Abstract

We investigate the effects of the 2014 international oil price bust on economic activity and fiscal outcomes in local oil-producing economies in Mexico. Using synthetic control estimators, we find that the 2014 price bust leads to a substantial decline in economic activity. We estimate an average gap in economic activity of 19.5% in the post-shock period between the realized outcome and the counterfactual scenario with no price shock. The largest estimated effect occurs in the southeastern state of Tabasco (21.6% decrease in economic activity). A collapse in local labor markets and government revenues follows. Fiscal transfers from the federal government do not act as a buffer, leaving local oil-producing states highly vulnerable to price fluctuations.

Keywords: Oil price shock, subnational economies, fiscal policy, synthetic control.
JEL Codes: E62, H71, H72, Q35.

Resumen

En este trabajo se analizan los efectos del colapso del precio del petróleo del año 2014, sobre la actividad económica y los ingresos fiscales de los estados productores de petróleo en México. Utilizando estimadores de control sintético, encontramos que el desplome del precio ocasiona una disminución sustancial de la actividad económica. Estimamos una brecha promedio en la actividad económica, en el periodo posterior al choque, de 19.5% entre la actividad observada y la actividad contrafactual sin la caída del precio del petróleo. El mayor efecto se produce en el estado de Tabasco (21,6% de disminución de la actividad económica). La caída del precio del petróleo también produce un deterioro importante en los mercados laborales y los ingresos fiscales locales. Las transferencias del gobierno federal no actuaron como amortiguador, lo que dejó a los estados productores de petróleo en una situación vulnerable ante la caída del precio del petróleo.

Palabras clave: caída del precio del petróleo, economías subnacionales, política fiscal, control sintético.
Códigos JEL: E62, H71, H72, Q35.

When Prices Go Awry: the Effects of an Oil Price Bust in a Subnational Oil-Producing Economy*

Gerardo Juárez† Emmanuel Chávez‡ Irvin Rojas§

July 9, 2024

Abstract

We investigate the effects of the 2014 international oil price bust on economic activity and fiscal outcomes in local oil-producing economies in Mexico. Using synthetic control estimators, we find that the 2014 price bust leads to a substantial decline in economic activity. We estimate an average gap in economic activity of 19.5% in the post-shock period between the realized outcome and the counterfactual scenario with no price shock. The largest estimated effect occurs in the southeastern state of Tabasco (21.6% decrease in economic activity). A collapse in local labor markets and government revenues follows. Fiscal transfers from the federal government do not act as a buffer, leaving local oil-producing states highly vulnerable to price fluctuations.

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1 Introduction

The Mexican federal government is highly dependent on oil revenues. Around 15 percent of its public budget relies on difficult-to-predict income streams from the oil industry (SHCP, 2024). At the national level, several mechanisms exist that allow accommodating negative shocks in international oil prices.[1] Nevertheless, a question remains on how negative global price shocks are translated to heavily oil-dependent local economies, as these automatic adjustment mechanisms are generally lacking for subnational governments. In the Gulf and Southern regions of Mexico, the states of Tabasco, Veracruz, Chiapas, and Tamaulipas have economies highly dependent on the oil industry. In the case of Tabasco, up to 48 percent of its GDP comes from the oil and gas industry (INEGI, 2024). Thus, the question we address in this paper is how international oil price shocks affect the economic and fiscal outcomes of such local economies.

In 2014, international oil prices declined sharply, from around 106 dollars per barrel in June to only 59 dollars per barrel by December (U.S. Energy Information Administration, 2024). This notable decline is associated with a significant oversupply in the global market, driven mainly by sustained production in the United States, explained by technological advances in shale oil production (Mead and Stiger, 2015). Contrary to usual practice, the Organization of the Petroleum Exporting Countries (OPEC) decided not to reduce its supply, adding downward pressure to international prices. On the other hand, demand in the main global markets was not strong enough to absorb this supply, partly due to a strengthening of the dollar against the major currencies of the buying countries (World Bank, 2018).

Price shocks can have major effects on local economic activity. First, a direct channel is through the impact on employment and aggregate demand in the local economy. Following the 2014 price shock, companies that provided services to *Petróleos Mexicanos* (PEMEX)– Mexico's oil monopoly for extraction– reduced their operations in the region; suppliers faced layoffs and a lack of payments, directly impacting the economic contribution crucial for

[1] In the Mexican case, these adjustment mechanisms include option contracts purchased from investment banks and swap lines from the US Federal Reserve and the Department of the Treasury. Section 2.2 describes this with more detail.

state development. Consequently, the finance ministry announced a budget cut of 100,000 million pesos (mdp) for PEMEX, including suspending several investment projects for 2016 (Forbes México, 2016). Reports showed that from 2014 to 2016, up to 12,000 PEMEX workers had been fired, contributing to a decline of about 30,000 jobs in the oil industry of Tabasco, a major oil-producing local economy (El País, 2016). The effects of oil price shocks on subnational economies are amplified because local economies are less diversified than national economies. Additionally, oil prices affect the industry's profitability, affecting employment and investment decisions in other non-oil-related sectors.

Oil price fluctuations also impact local economies through their effect on government finances. Governments in oil-producing economies obtain important income streams from the value of royalties and, in some cases, from the revenues of publicly owned oil companies. Furthermore, fiscal revenues depend on overall economic activity. If output collapses, government revenues are set to fall. The fiscal and economic local shock may not be counteracted if national governments do not transfer additional funds to oil-dependent subnational economies.

This paper uses the 2014 oil price bust as a natural experiment to study the economic and fiscal effects of Mexico's oil-producing subnational economies. We use the synthetic control (SC) methodology proposed by Abadie and Gardeazabal (2003); Abadie et al. (2010, 2015). Our treatment units are the states where oil output is a sizable component of total GDP. We construct the synthetic counterfactual with the states where oil output is virtually non-existent. We estimate an average gap in economic activity of 19.5 percent in the post-oil price shock period between the realized outcome and the counterfactual scenario with no price shock. The largest estimated effect occurs in Tabasco (21.6 percent decrease in economic activity). Moreover, we find strong evidence that the economic decline caused by the oil price bust led to a deterioration of the local labor markets. We observe a sharp decrease in total employment compared to the synthetic counterfactual and a lagged negative effect on labor earnings.

In addition, the 2014 oil price bust led to a collapse in government revenues. This affected revenues directly tied to oil output (royalties) and revenues linked to the overall economic activity (value-added tax). Transfers from the federal government did not counteract the local revue collapse. On the contrary, we find some (non-statistically significant) evidence that federal transfers decreased following the oil price bust. As federal transfers compose the lion's share of state governments' revenues, local oil-producing economies in Mexico are highly vulnerable to oil price busts. Our research highlights the importance of including a countercyclical component for federal transfers to subnational governments facing external shocks.

We build on current literature in two main ways. First, by studying economies at the subnational level, as literature on oil-price shock effects deals primarily with national-level impacts. However, the effects of energy price shocks at subnational levels can be more nuanced and explained by institutional arrangements and the actual rules and discretion governing the relationship between them. Few papers study these local effects, and they focus on the labor market, not on overall economic activity or the fiscal consequences of the shock (Black et al., 2005; Marchand, 2012). Second, we build on the literature by using a methodology dealing with endogeneity. Most papers studying oil price shocks use panel data or vector autoregression (VAR) methods that do not take a control group as a counterfactual to infer the causal effects in the treatment group, which puts into question the causal validity of the effects they find.[2]

1.1 Related literature

There is a large body of research on the effects of oil price shocks on economic activity. The earliest literature focused mainly on high-income countries. These countries are commonly net oil importers. One of the earliest studies is that of Hamilton (1983), who noted that a sharp increase in oil prices preceded most of the United States' recessions following World War II. Burbidge and Harrison (1984) extended this finding to five high-income countries

[2]One exception is the study by Jarrett et al. (2019). They use the synthetic control method in the context of the 2014 oil price bust to estimate the moderating effect of financial institutions' quality when facing financial shocks. Munasib and Rickman (2015) do not study an oil price shock but use a similar strategy to ours to study the effects of the shale gas and oil boom. Another paper using methods to deal with endogeneity is Bunce and Carrillo-Maldonado (2023). They use local protections (LP) to study the asymmetric effects of oil price shocks in Ecuador.

(U.S., UK, Germany, Japan, and Canada). A similar conclusion is reached by Gisser and Goodwin (1986), Hooker (1996) and Blanchard and Galí (2009). However, Blanchard and Galí (2009) argue that in the 2000s, oil increases had smaller effects on output. This is later confirmed by Blanchard and Riggi (2013).

Mork (1994) and Hamilton (2003) analyze asymmetric effects of oil price shocks in high-income countries. They find that oil price increases have a much larger impact on output than oil price decreases in the United States. Jiménez-Rodríguez and Sánchez (2005) extend the asymmetry analysis to the leading industrialized countries and find that oil price increases have a large negative effect on GDP growth. In contrast, oil price decreases have a non-statistically significant impact. The exception is Norway, a rich oil-exporting country.[3]

Since the 2000s, literature on the effects of oil price shocks has studied middle-income oil-exporting economies. The studies have found that price increases tend to benefit these economies, while price decreases tend to harm them. Eltony and Al-Awadi (2001) study the impact of oil price decreases in Kuwait, an oil exporting country whose economy is highly dependent on oil exports. They find that decreases in oil prices have a negative impact on GDP. El Anshasy et al. (2005) find that higher oil prices lead to higher GDP in Venezuela, while lower oil prices lead to lower output. Farzanegan and Markwardt (2009) studies oil price shocks in the Iranian economy. They find that oil price increases have a positive effect on industrial output, while oil price decreases have a negative impact on industrial output. Bunce and Carrillo-Maldonado (2023) find that oil price decreases have a negative effect on the Ecuadorian economy, while oil price increases have a positive impact. In addition, the effect on output is larger for price decreases than for price increases.[4]

Other papers have studied the effects of oil price shocks in a panel of countries. Nusair (2016) studies oil price shocks for countries in the Gulf Co-operation Council (oil-rich coun-

[3]Researchers have also studied asymmetric effects depending on the source of the oil price shock. Baumeister and Hamilton (2019) and De et al. (2022) find that oil price increases coming from oil supply shocks have a negative effect on U.S. output, while those coming from a demand shock (due to world demand expansions) have a positive impact on U.S. output. Peersman and Van Robays (2012) study eleven industrialized countries. They find that oil price increases driven by oil supply shocks lead net importing countries to a decline in output. In contrast, the impact on net energy exporters is insignificant or positive. Oil price increases driven by demand shocks lead all countries to a transitory increase in GDP.

[4]An exception is the paper by González and Hernández (2016). They find that oil price increases have a negative impact on Colombian output, while price decreases do not have an effect.

tries in the Arabian Peninsula). The author finds that oil price increases lead to increased GDP in all countries, while the effect of oil price decreases is not always significant. Togonidze and Kočenda (2022) study emerging economies with varying resource endowments in Latin America, Europe, and Asia. They find that oil-exporting economies experience GDP booms following oil price increases while oil-importing economies experience a contraction. Mineral-intensive oil-importing economies can cushion this contraction with mineral exports. Thus, research generally finds that oil-price booms hurt high-income oil-importing economies while middle-income oil-exporters are favored. Oil price busts do the opposite; they hurt oil exporters while oil importers benefit. However, the effect of price busts is not always significant on oil exporters.

Literature has also looked at the fiscal effects of oil price shocks. This is an important factor as some evidence indicates that the impact of oil prices on oil-producing countries goes mostly through fiscal policy (Husain et al., 2008). Some papers find that oil-producing countries' fiscal policies behave pro-cyclically following oil price booms (Fasano and Wang, 2006; Lopez-Murphy and Villafuerte, 2010; Erbil, 2011). However, more recent papers are less conclusive about the procyclicality of these countries' fiscal policies. Céspedes and Velasco (2014) study 32 commodity producers in the 1900-2010 period. They find fiscal policy in commodity economies was pro-cyclical in the 1970s and 1980s, following commodity price booms. However, by the 2000s, procyclicality diminished in several countries due to reduced procyclicality of government expenditure during booms. El Anshasy and Bradley (2012) study 16 oil-producing countries and also find a pro-cyclical behavior in fiscal policy following oil-price booms. However, they find that the increase in oil revenues is larger than in public spending, indicating that oil producers save part of the extra revenues.

Finally, a set of papers finds clear evidence of countercyclical fiscal policy. Farzanegan and Markwardt (2009) find that the fluctuations in oil prices have little impact on public spending in Iran. Eltony and Al-Awadi (2001) finds that Kuwait tends to save excess fiscal revenues during price booms and maintains public spending during price busts. Arezki and Ismail (2013) study 32 oil-producing countries and find that current government spending is downwardly rigid during oil price busts. Thus, while there's evidence of some pro-cyclical behavior of oil-producing countries during price booms, most papers find countercyclical behavior in the last decades, especially during price busts. National governments in oil-producing countries tend to use fiscal buffers to soften the effect of oil price busts on the economy. Our study fills a gap in the current literature by analyzing the economic impact of an oil price bust on subnational economics, as well as the fiscal reaction to soften the shock's impact at the local level.[5]

The rest of the paper proceeds as follows: section 1.1 mentions relevant literature; section 2 describes the 2014 oil price shock and revises the legal framework that defines government spending in Mexico; section 3 details the data sources and the methodology we use; section 4 presents our results; finally, section 5 concludes.

2 Context and institutional setting

2.1 The 2014 oil price bust

In the three years before the June 2014 oil price bust, from January 2011 to June 2014–, the average daily price of the West Texas Intermediate crude oil –the benchmark for pricing in North America– was 96 USD per barrel. This unprecedented high level was only briefly reached just before the 2008 global financial recession. By the end of June 2014, international oil prices experienced one of the sharpest declines in recent history. Panel (a) of Figure 1 shows the daily price of the main global crude oil benchmarks, as well as Mexico's benchmark (*mezcla mexicana*). From June 20th, 2014, to January 6th, 2015, the average price of these benchmarks went from 110 to 48 USD per barrel, a 56 percent price decrease in six months. While the oil price continued to decline until January 2016, the declines after January 2015 were comparatively lower than the reduction experienced in the second semester of 2014.

[5]While some papers study the effect of price shocks on local employment outcomes, we know of no paper studying the fiscal reaction to these shocks at the local level. Black et al. (2005) study a coal price boom and bust on local economies in the United States (Kentucky, Ohio, Pennsylvania, and West Virginia). They find positive (negative) effects on employment, wages, and migration from the coal price boom (bust). Marchand (2012) examines the impact of energy price booms and busts in local economies in Western Canada with similar findings. Munasib and Rickman (2015) study the shale gas and oil boom in Arkansas, North Dakota, and Pennsylvania. They found that the sector's expansion had positive employment effects in North Dakota and Arkansas but no effects in Pennsylvania.

Oil prices did not recover their pre-June 2014 level in the following years.[6]

Panel (a) of Figure 1 shows clearly that Mexico's price benchmark follows international benchmarks closely. Indeed, Mexico is a price taker in the global oil markets. Although the country is a relatively important player, producing around two percent of the international oil supply, its production is not sufficiently big to have a determining impact on global prices. Panel (b) focuses on the price of the Mexican Oil Mix (*mezcla mexicana de petróleo*). This is a weighted price average of different oil types produced by *Petróleos Mexicanos* (PEMEX), Mexico's state oil company. This price benchmark is the reference for estimating key macroeconomic variables, such as government revenues. From June 20th, 2014, to January 15th, 2015, the Mexican Mix price went from 102.4 to 38.5 USD per barrel, a 62 percent decline.

The 2014 oil price collapse was caused by a combination of supply and demand factors (Mead and Stiger, 2015; World Bank, 2018) beyond Mexico's control. First, the years leading up to 2014 experienced a surge in the United States' shale oil production. U.S. shale oil represented around half the growth in total oil production. Second, as prices collapsed, the Organization of Petroleum Exporter Countries (OPEC) decided not to reduce oil output, favoring instead retaining market share. On the demand side, growth prospects deteriorated in commodity-exporting economies, China, Europe, and the United States, leading to a decline in oil consumption. All these factors are exogenous to Mexico, particularly Mexico's oil-producing states.

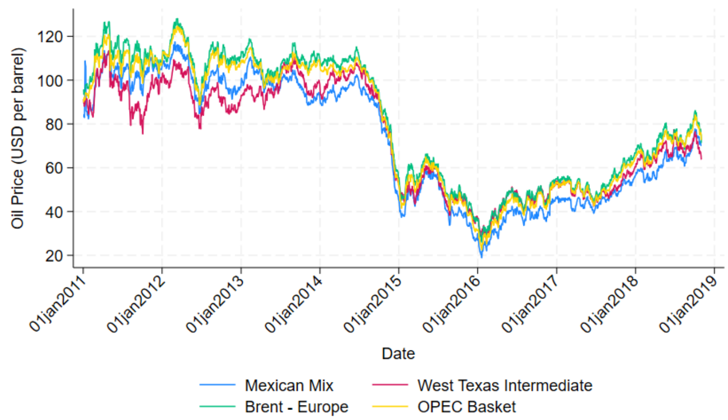
2.2 Institutional setting

In Mexico, oil extraction is mainly carried out by *Petroleos Mexicanos* (PEMEX), a state company owned at the federal level. The federation directly taxes oil revenues from PEMEX. Before the 2014 oil price bust, around 30 percent of the federal government's total revenues came from taxes imposed on oil production (SHCP, 2013). Given the importance of oil revenues, the federal government has established a legal framework to guarantee a minimum oil price. Every year, the Mexican Congress discusses *Ley de Ingresos de la Federación* (LIF);

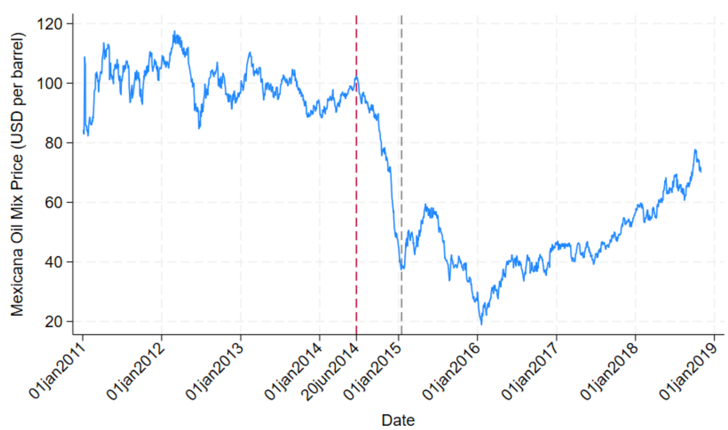
[6]It took until March 2022 for prices to briefly reach 2011-2014 levels. However, since August 2022, prices have fallen to the 75 USD per barrel range.

Figure 1: Benchmark oil prices 2011-2019

(a) International reference markets



(b) Mexican market



Note: figure in Panel (a) plots the oil price in four international reference markets. The 2014 oil bust is evident in all four series. Figure in Panel (b) shows the oil price in the Mexican market. Sources: *Sistema de Información Económica* (SIE) by *Banco de México*, Federal Reserve Economic Data (FRED) dataset by the Federal Reserve Bank of St. Louis, and OPEC basket price by the Organization of Petroleum Exporting Countries.

the law is approved in November and sets an estimate for government revenues the following year. Estimates of oil revenues are based on an oil price and production forecast. Articles 31 and 21bis of *Ley Federal de Presupuesto y Responsabilidad Hacendaria* (LFPRH) mandate the Ministry of Finance to buy financial instruments to ensure the oil price level set in LIF throughout the upcoming year (Congreso de la Unión, 2014).[7] Thus, the federal government budget is protected from oil price fluctuations. However, no such strategy exists at the state level.

The federal government not only collects the lion's share of oil revenues, it also collects most tax revenues. The federation collects around 78 percent of total tax revenues in Mexico. States only collect 2.5 percent of the total (OECD et al., 2023).[8] As states directly collect a relatively small amount of government revenue, most of their revenues depend on transfers from the federal government. Around 81 percent of total state government revenues are provided by the federation (IMCO, 2022). Federal transfers to state governments are divided into two main groups: earmarked transfers (*aportaciones*) and non-earmarked transfers (*participaciones*). Earmarked transfers have spending conditions and items set by the federal government, while non-earmarked transfers can be spent on items state governments can freely choose.[9]

Both earmarked and non-earmarked transfers are set according to formulas specified in *Ley de Coordinación Fiscal* (LCF). Each federal fund has a specific formula according to the fund's objective (Congreso de la Unión, 2013). However, all formulas are set in a pro-cyclical manner, as the transfer T to state i on time t depends positively on economic activity:

$$T_{i,t} = T_{i,t-\tau} + \alpha Y_{i,t} + \beta X_{i,t}$$

[7]The institutional framework also protects federal oil revenues from variation in oil output via *Fondo de Estabilización de los Ingresos Petroleros*, renamed in 2014 as *Fondo de Estabilización de los Ingresos Presupuestarios*.

[8]The main taxes, such as the value-added, income, or corporate tax, are entirely in the federal government's jurisdiction. States collect more minor taxes, such as the payroll tax or taxes on car ownership.

[9]The specific funds composing both types of transfers are: 1) Earmarked transfers: *Fondo de Aportaciones para la Infraestructura Social*, *Fondo de Aportaciones para el Fortalecimiento de las Entidades Federativas*; non-earmarked transfers: *Fondo General de Participaciones*, *Fondo de Fiscalización y Recaudación*, *Fondo de Fomento Municipal*, *Fondo de Compensación*.

where $t - \tau$ denotes a reference year, Y is economic activity and X is a set of socio-economic variables. There is no countercyclical component in the formulas that determine federal transfers to states. Leaving state government revenues highly vulnerable to negative shocks on local economic activity.[10]

3 Data and methodology

3.1 Data

Mexico's **oil price** data is generated by *Petróleos Mexicanos* (PEMEX). We take the *mezcla mexicana de petroleo* price, a price average of different oil types produced by PEMEX. We gather the data from *Sistema de Información Económica* (SIE) by *Banco de México*. West Texas Intermediate and Brent oil price data come from the Federal Reserve Economic Data (FRED) dataset created by the Federal Reserve Bank of St. Louis. Finally, the OPEC basket price comes from the datasets of the Organization of Petroleum Exporting Countries. All oil prices are provided at the daily time frame.

As a measure of **economic activity**, we use *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE). This is a unique set of information provided by *Instituto Nacional de Estadística y Geografía* (INEGI). It is an index widely used in Mexico to measure economic activity at the state level. We use ITAEE instead of state GDP due to ITAEE's quarterly frequency compared to the yearly frequency of state GDP. Around 90 percent of total state production is covered by ITAEE. The quarterly frequency provides more data points, improving the quality of our synthetic control.[11] Only eight out of 193 United Nations countries produce a regional quarterly index of economic activity (INEGI, 2023). ITAEE's information frequency, combined with the fact that Mexico has a clear oil-producing region, permits a precise estimation of the effects of an oil price collapse on regional economic activity.

[10]There is one federal fund aimed at oil-producing states: *Fondo de Estabilización de Extracción de Hidrocarburos*. This fund compensates states when they suffer a shock in their extraction levels. Thus, it has a countercyclical character. However, it only covers losses in production, not changes in prices.

[11]According to Abadie et al. (2010), large numbers of pre-intervention periods allow better control for the responses to unobserved factors.

Labor market outcomes come from *Encuesta Nacional de Ocupación y Empleo* (ENOE). This is a household survey measuring labor and socioeconomic characteristics. INEGI produces it quarterly and is representative at the national and state levels. From ENOE, we get the total number of employees by state and their mean labor earnings.

We use two data sources to measure **government revenues**. For revenues the federal government collects, we use INEGI's *Anuario Estadístico y Geográfico por Entidad Federativa*. It is a yearbook that covers many economic variables at the state level, including taxes collected in each state's territory by the federation. For revenues states collect directly, we use the dataset *Estadística de las Finanzas Públicas Estatales y Municipales* (EFIPEM) created by INEGI. It covers the universe of revenues collected at the state level. It also provides information on other sources of state revenues, such as funds transferred by the federal government. All revenue data is provided yearly.

3.2 Methodology

In this paper, we use a synthetic control approach to estimate the economic impact of the 2014 oil price bust on the local economy in a Mexican region highly dependent on oil revenues. The synthetic control approach has been extensively used in causal inference problems when only one or a few units receive a treatment. The method allows a systematic treatment of event studies. The objective is to build a synthetic unit representing the unobserved counterfactual of the treated unit by exploiting the information on a group of non-treated units known as the *donor pool*. It is frequently the case that the average characteristics and outcomes of the donor pool are not a good representation of the counterfactual of the treated unit. Nevertheless, by estimating the synthetic control, the characteristics of the donor pool are optimally accounted for when constructing a unit that represents the treated unit under the non-treatment regime.

The synthetic control method for one treated unit can be formalized as follows.

Consider $J+1$ units, with $2, ..., J+1$ indexing the non-treated units or the donor pool. Time is indexed by $t = 1, ..., T$ analysis periods, with an intervention occurring at T_0, affecting only unit $j = 1$. Assume that before T_0 no unit is treated. Consider the two counterfactual outcomes with treatment and with no treatment, Y_{it}^I and Y_{it}^N, respectively, so $Y_{it}^N = Y_{it}^I$ for $t < T_0$.

Under this setting, the treatment effect is given by $\alpha_1 = (\alpha_{1T_0+1}, ..., \alpha_{1T})$ for $t \geq T_0$, with $\alpha_{1t} = Y_{1t}^I - Y_{1t}^N$. The main problem of causal inference arises because Y_{1t}^N– the counterfactual outcome of the treated unit under no treatment– cannot be observed. The synthetic control method seeks to provide a reasonable estimate of this unobserved outcome.

Following Abadie (Abadie et al., 2010), consider a general model of the outcome of interest:

$$Y_{it}^N = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it}$$

where Z_i are observed characteristics not affected by the intervention.

A synthetic control is a vector of weights $W = (w_2, ..., w_{J+1})$, with $w_j \geq 0$ for $j \geq 2$, with $w_2 + \ldots + w_{J+1} = 1$. An infinite amount of synthetic controls represents a weighted average of the units in the donor pool. Thus, the outcome of a synthetic unit can be written as:

$$\begin{aligned} Y_{Wt}^N &= \sum_{j=2}^{J+1} w_j Y_{jt} = \\ &= \delta_t + \theta_t \left(\sum_{j=2}^{J+1} w_j Z_j \right) + \lambda_t \left(\sum_{j=2}^{J+1} w_j \mu_j \right) + \left(\sum_{j=2}^{J+1} w_j \varepsilon_{jt} \right) \end{aligned}$$

Suppose there is a vector of weights W^* such that the synthetic control replicates the treated unit in the pre-intervention period. That is:

$$\sum_{j=2}^{J+1} w_j^* Z_j = Z_1$$

Then, it can be shown that the synthetic control replicates the outcome variable in the pre-intervention period as well:

$$\sum_{j=2}^{J+1} w_j^* Y_{jt} = Y_{1t} \quad \forall t \in 1, ..., T_0$$

Abadie et al. (2010) provide formal conditions under which the synthetic control can be built. Under this setting, the treatment effect for the post-intervention period can be estimated as follows:

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} = Y_{1t} - Y_{W^*t}$$

for $t \in \{T_0 + 1, \ldots, T\}$.

3.3 Estimation

A requirement for estimating the synthetic control is to have pre-treatment period observations that credibly replicate the treated unit before the treatment.

To estimate the synthetic control, define the vector $X_1 = (Z_1', \tilde{Y}_1^{K_1}, \ldots, \tilde{Y}_1^{K_M})$ as containing observable characteristics of the treated unit, together with M linear combinations of the outcome variable in the pre-intervention period. Analogously, define the matrix X_0 as containing the same data but for the donor pool. Also, a discrepancy measure between X_1 and X_0 is defined as $X_1 - X_0 W$. The synthetic control seeks to minimize the quadratic form associated with this discrepancy measure:

$$\min_{W \in \mathcal{W}} (X_1 - X_0 W) V' (X_1 - X_0 W)$$

with V being positive definite.

The solution to this optimization problem is $W^*(V)$, which depends on V. Following Abadie et al. (2010, 2015), we choose V to reflect the relative importance of elements in X_0 and X_1 in predicting the outcome in the preintervention period. We can then select V to minimize the distance between the observed outcome and the counterfactual defined by $W^*(V)$.

Define $\mathcal{Y}_1$ as the outcome of the treated unit in the pre-intervention period, while $\mathcal{Y}_0$ is the matrix of outcomes of the donor pool in the same period. An optimal V can then be chosen as:

$$V^* = \arg\min_{V \in \mathcal{V}} (\mathcal{Y}_1 - \mathcal{Y}_0 W^*(V))'(\mathcal{Y}_1 - \mathcal{Y}_0 W^*(V))$$

The synthetic control is given by $W^*(V^*)$.

For our empirical application, we choose a set of variables for X_0 and X_1 that predict economic activity and tax revenues, including a quarterly economic activity index for the electric industry and water and gas distribution sector (sector 22) and for the manufacturing industry (sector 31-33), a quarterly index of employment in construction, the quarterly unemployment rate, and the yearly amount of gross fixed capital formation.

4 Results

4.1 Effects on economic activity

To estimate the effect of the oil price shock on economic activity, we proceed in two ways. First, we define an oil-producing *region* composed of the leading oil-producing states. Second, we estimate the effect on each of these oil-producing states separately. These are states where the value of oil production exceeded one percent of GDP when the oil price collapsed and have maintained relatively constant oil production levels in the years before the price bust. The states that meet these criteria are Tabasco (48.8% oil share of GDP), Veracruz (5.2%), Chiapas (4.4%), and Tamaulipas (3.2%).[12] We exclude Campeche, an important oil-producing state, from our oil region due to its declining production trend in the last decades. The declining production trend does not permit the isolation of the effect of a price collapse instead of a production contraction.[13]

For the oil region, we construct Y_1 as the weighted average of *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE) for the $i = 4$ states included in the region. Each state i's weight ω_{it} is calculated based on its share in the region's total oil output, expressed

[12] Figure A1 provides a map of the states that compose the oil-producing region.

[13] As Figure A2 shows, oil production in Campeche has contracted from around 3,000 million oil barrels per day (bpd) in 2004 to about 1,000 million bpd in 2024. Thus, production fell by about two-thirds in two decades. This drastic output collapse is particular to Campeche. The other oil-producing states display relatively constant levels of production.

in monetary terms:

$$\omega_{it} = \frac{\text{Oil Production}_{it}}{\sum_{i=1}^{4} \text{Oil Production}_{it}}$$

The weights are calculated yearly. Each annual weight is assigned to the four quarters that compose a given year t. Panel (a) of Figure 2 shows the evolution of ITAEE in the oil-producing region (blue line) vs. the region's synthetic control (red line). The donor pool to construct the synthetic ITAEE comprises 23 states. These are the states where oil output is virtually non-existent. The graph shows similar trends among the synthetic and actual oil regions before the oil price bust (second quarter of 2014). After the shock, the trends diverge. Economic activity in the actual oil region decreases after the price shock occurs. In contrast, the counterfactual (the synthetic ITAEE) continues to grow. i.e., if the oil price bust had not occurred, the oil region's economic activity would not have decreased. The average difference between the oil-producing region's actual and synthetic ITAEE amounts to a 19.5 percent decrease. This is a sizable negative effect on economic activity.[14]

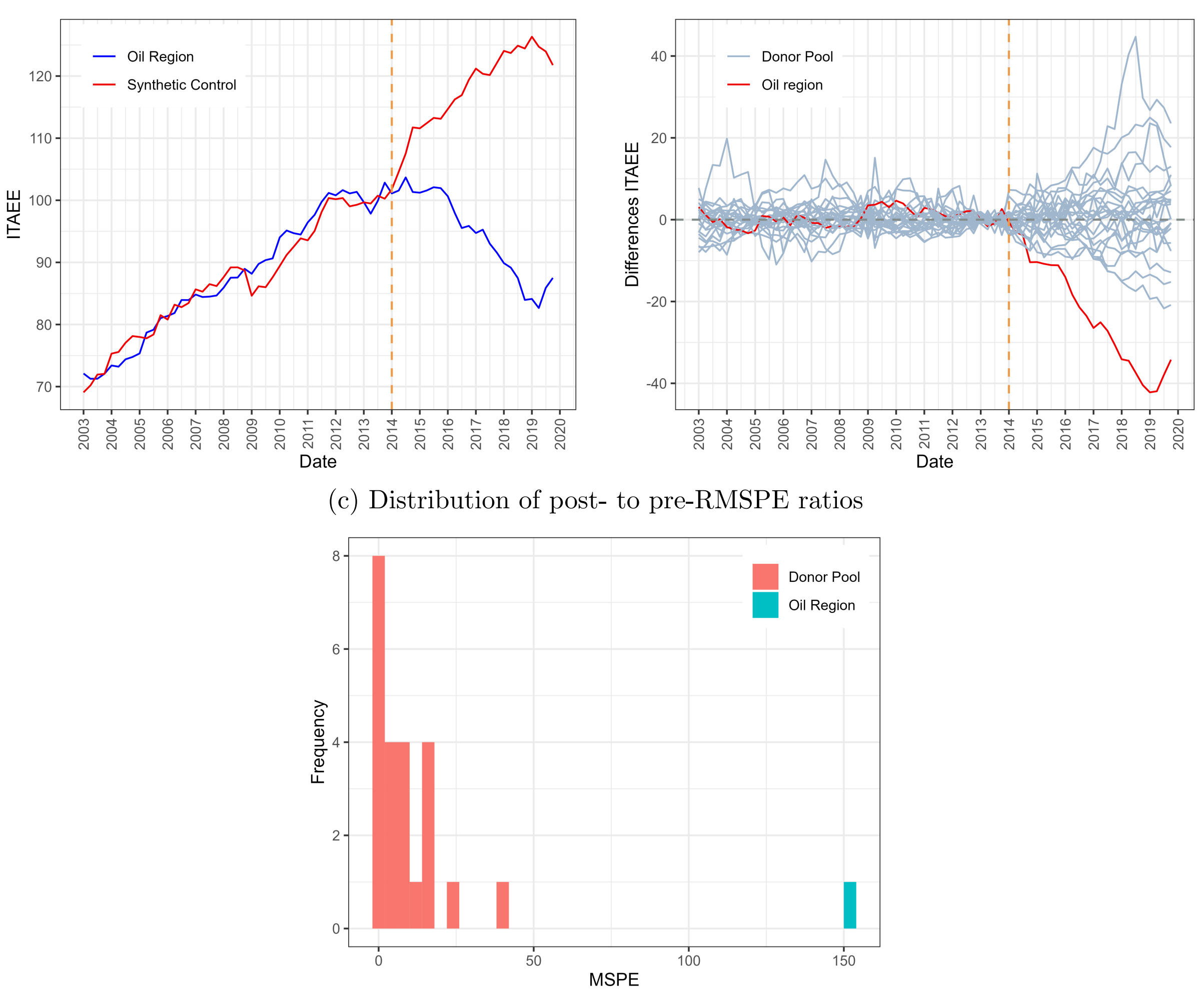
Panel (b) of Figure 2 shows placebo tests proposed by Abadie et al. (2010). We take each state in the donor pool, and for each state, we calculate its synthetic control. The graph plots the gap between the actual vs. the synthetic ITAEE for each donor state. The biggest post-treatment gap is that of the oil region (shown in red). To calculate the statistical significance of the oil price shock effect on economic activity, we calculate the root mean squared prediction error (RMSPE) values for the pre and post-treatment period for each state in the donor pool. Then, we compute the ratio of the post to pre-treatment RMSPE. Panel (c) displays the histogram of the ratio distribution. The oil region's ratio ranks first out of 23 states in the donor pool. This corresponds to a 0.041 p-value, which provides statistical significance at conventional levels.[15]

Let us now discuss the effect of the 2014 oil price bust on the economic activity of each state in the region separately. Figure 3 plots each state's actual vs. synthetic ITAEE. The

[14]In the first column of Table A1, we show the weights each state in the donor pool assigns to the oil region's ITAEE synthetic control. The table also shows the synthetic control weights for all the other outcomes in this paper.

[15]Following Abadie et al. (2010), we calculate $p = \frac{\text{treatment unit rank}}{\text{number of units in the donor pool}}$.

Figure 2: Effect of the oil price shock on the oil region's economic activity



(a) Oil region's ITAEE vs. synthetic oil region

(b) Placebo distribution

(c) Distribution of post- to pre-RMSPE ratios

Note: Panel (a) depicts the realized economic activity trajectory in the Mexican oil region, together with the estimated synthetic control trajectory. Panel (b) depicts the distance between Panel (a) trajectories with a red line. Gray lines show the estimated placebo gaps between each non-oil region state and their synthetic control. The oil region gap has the sharpest estimated decline. Panel (c) shows the RMSPE associated with the gap in Panel (a) and with the placebo estimates in Panel (b), ranked by their magnitude. The RMSPE associated with the estimated economic activity gap for the oil region is the largest among the estimated placebo gaps and is thus considered *statistically significant*. Sources: *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE) by *Instituto Nacional de Estadística y Geografía* (INEGI).

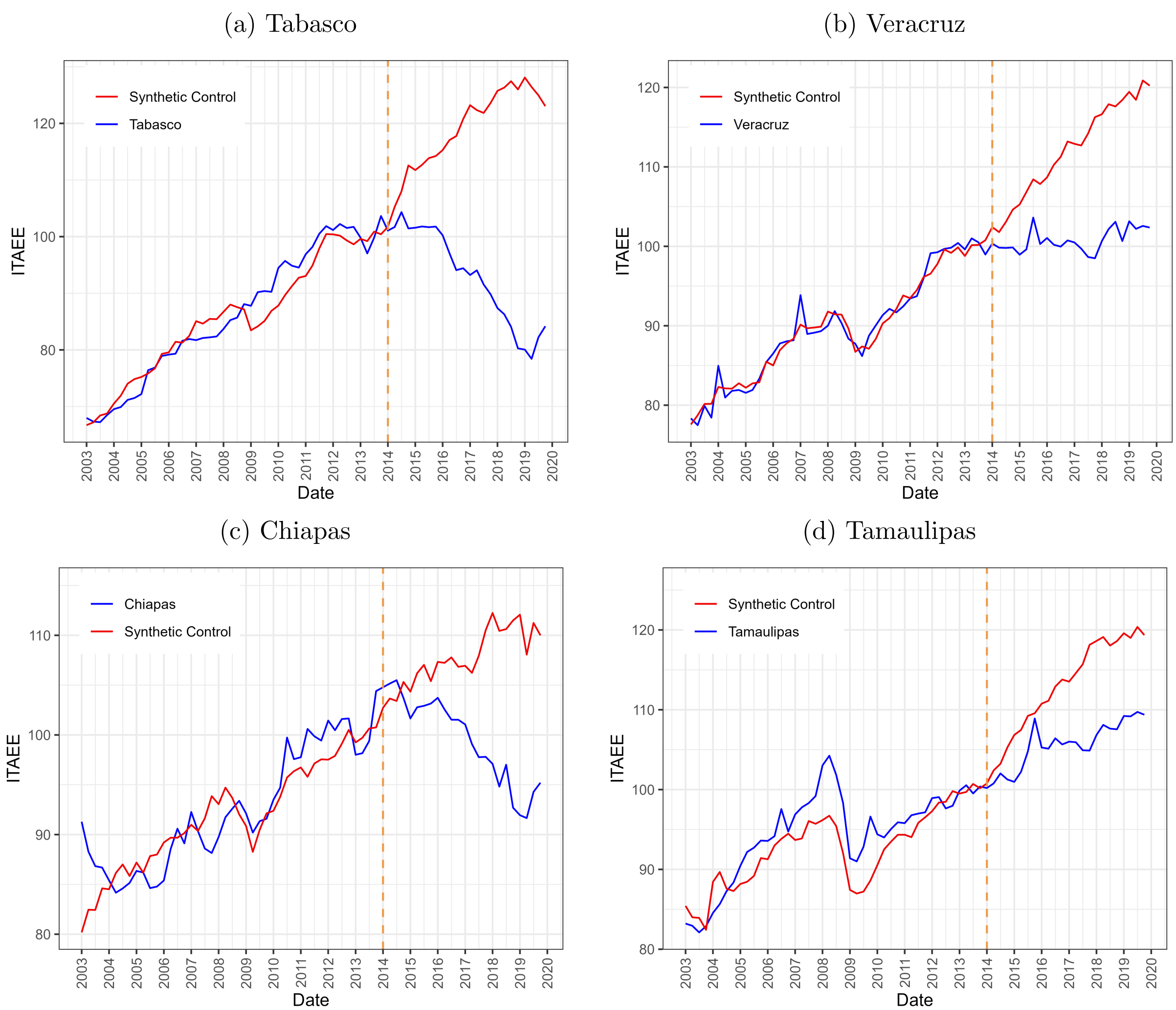
synthetic ITAEE closely follows the actual ITAEE before the price bust for all states. After the shock, the actual vs. synthetic trends diverge. In addition, the figure gives graphical evidence that the largest oil price bust impact happened in Tabasco (Panel a). Indeed, the average difference between Tabasco's ITAEE and the synthetic control's ITAEE in the post-treatment period amounts to a 21.7 decrease in economic activity. This is two times larger than Veracruz, the state with the second largest decline (Panel b). The difference between Veracruz's ITAEE and its synthetic control amounts to a ten percent decline. The decline is smaller for Chiapas and Tamaulipas (Panels c and d), amounting to 7.6 percent and 6.5 percent, respectively.

Regarding statistical significance, Figure 4 shows each state's histograms of the post- to pre-RMSPE ratios. For Tabasco and Veracruz, the histograms rank the RMSPE in the first of 23 states, corresponding to a pseudo-p-value of 0.041, which falls under conventional statistical significance. Chiapas and Tamaulipas rank fourth and fifth, respectively (0.21 and 0.25 p-values). The effect is thus not statistically significant for these states.

The results we get by state are intuitive as Tabasco had, by far, the largest share of oil output in its GDP before the oil price bust: half of Tabasco's output was tied to oil production. This relatively large dependence on oil led to a substantial decline in Tabasco's economic activity compared to a synthetic counterfactual that depicts what economic activity would look like without the price bust. The effect is also statistically significant for the state with the second-largest share of oil output in total GDP: Veracruz. As the importance of oil output in GDP decreases, the effects we find have the expected sign but become non-statistically significant. This does not mean that the oil-price bust did not impact Chiapas' and Tamaulipas' GDP; it means that we cannot detect a statistically significant causal effect with the method we use. Moreover, a smaller negative impact in states with lower oil output to GDP ratio supports that the effects we find are due to the price bust instead of other unobserved factors.[16]

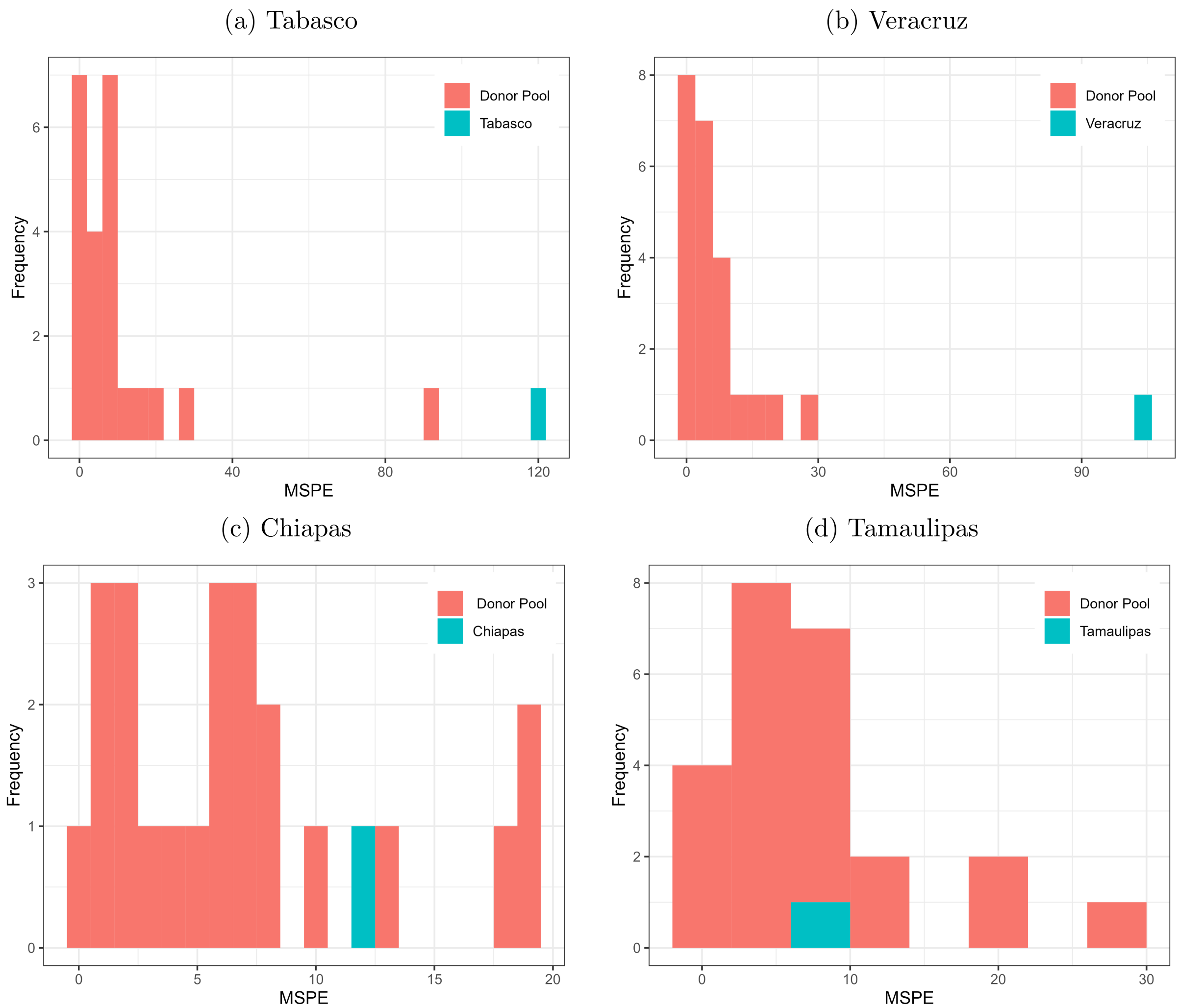
[16]Figure A3 shows robustness tests on our synthetic control estimates for the ITAEE outcome, both on the oil region and each state separately. The test consists of constructing the synthetic control assuming that the treatment (the oil price bust) occurs in the first quarter of 2012. If this test showed that the synthetic control trajectory diverges in the 2012q1, it would give evidence that other non-observed factors cause the ITAEE negative effect. However, Figure A3 does not show that. The figure shows that even if we assume

Figure 3: ITAEE vs. synthetic ITAEE by state



Note: this figure shows the realized economic activity trajectory in the four Mexican states that belong to the oil region, together with the corresponding estimated synthetic control trajectory. The average estimated economic activity gap in the post-shock period occurs in Tabasco (27.5% decrease), followed by Veracruz (10%), Chiapas (7.6%), and Tamaulipas (6.5%). Sources: *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE) by *Instituto Nacional de Estadística y Geografía* (INEGI).

Figure 4: Distribution of post- to pre-RMSPE ratios by state



Note: this figure plots the estimated RMSPE associated with the differences between the realized and the synthetic trajectories illustrated in figure 3. Each Panel also shows the estimated RMSPE for each unit in the donor pool, ranked by magnitude. The RMSPE of Tabasco and Veracruz are by far larger than every RMSPE of the donor pool units. Thus, the estimated effect for these states is considered *statistically significant*. The effects in Chiapas and Tamaulipas are less extreme than in some placebo units. Sources: *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE) by *Instituto Nacional de Estadística y Geografía* (INEGI).

Other local outcomes should reflect the negative impact on local economic activity caused by the oil price bust. To examine this, we calculate the effect of the 2014 price bust on the local labor market. Panels (a) and (b) show evidence of the impact on the employment level of the oil-producing region. The region's employment is obtained as a weighted average of the four states that compose it.[17] As shown in Panel (a), the actual and synthetic employment level trajectories evolve similarly before the oil price bust. Following the bust, we observe an important decline in the actual trajectory while the synthetic trajectory continues to grow. This denotes an important negative impact of the oil price bust on the local employment level; the effect is statistically significant (p-value of 0.04), as shown in Panel (b).

Panel (c) depicts the actual and synthetic trajectories for the weighted average earnings of the employed population in the oil-producing region. The panel gives some evidence that the price bust also led earnings to decline as the synthetic and actual trajectories adjusted well before the 2014 price bust. However, we do not see an immediate effect as we saw with the employment outcome. In the case of earnings, the actual and synthetic trajectories diverge in 2016; this is a two-year lag concerning the oil price bust. If the effect we find in Panels (a) and (c) does come from the oil price bust, the evidence indicates that the negative economic shock was immediately reflected in less employment than the region would have in the absence of the shock. However, there appears to be no effect on labor earnings in the two years that follow the shock. After two years, mean earnings in the oil-producing region decrease (compared to the counterfactual), probably due to a deteriorated labor market that improves firms' bargaining power vis-à-vis employees.

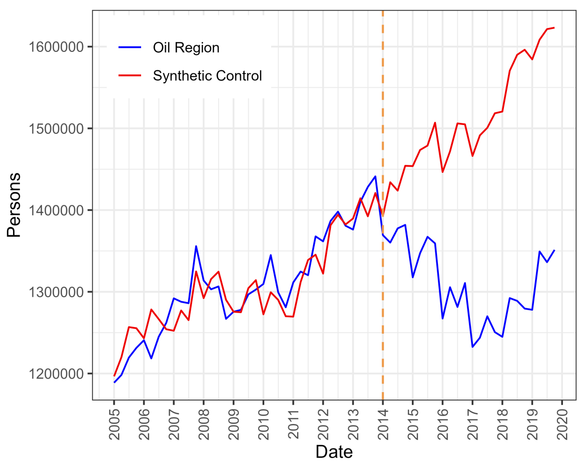
Our labor market findings are similar to Black et al. (2005). They study the effects of a coal price boom and bust on coal-producing states in the United States (Kentucky, Ohio, Pennsylvania, and West Virginia). They find negative effects on employment, wages, and migration due to the coal price bust. We improve on their paper by using a methodology that deals with endogeneity, as Black et al. (2005) use first difference regressions that do not take a control group counterfactual. Our findings are also in line with Marchand (2012). He

the treatment period to be 2012q1, the synthetic control diverges until 2014 when the actual oil price bust occurs. This falsification test supports that the negative effect on ITAEE is due to the shock in oil prices.

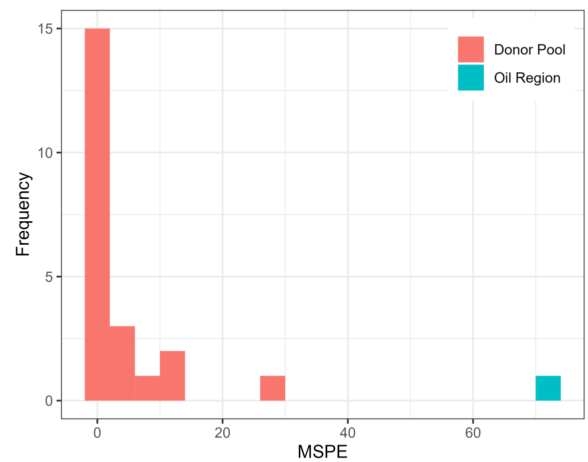
[17] The weights are constructed in the same form as for the ITAEE outcome.

Figure 5: Labor market outcomes in the oil-producing region

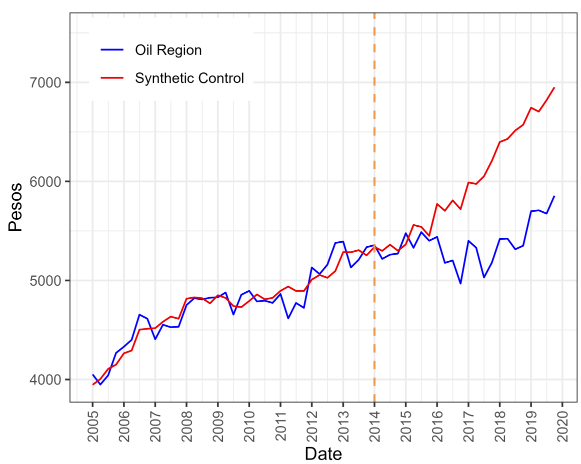
(a) Employment - actual vs. synthetic



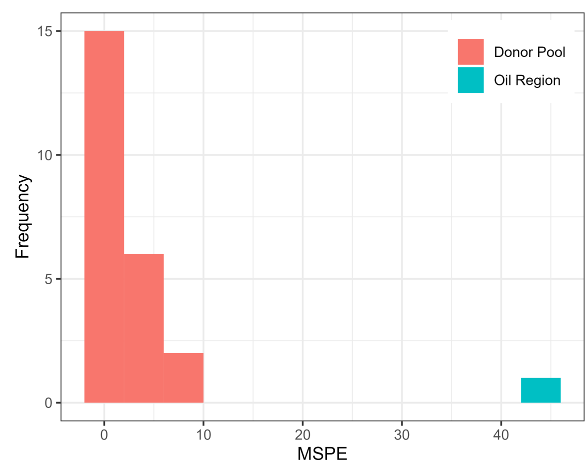
(b) Employment - actual vs. synthetic



(c) Avg. Earnings - RMSPE ratios



(d) Avg. Earnigs - RMSPE ratios



Note: Panels (a) and (c) show the realized trajectories of the employment level and average earnings in the oil-producing region, together with the corresponding estimated synthetic control trajectory. Panels (b) and (d) plot the estimated RMSPE associated with the differences between the realized and the synthetic trajectories. They also show the estimated RMSPE for each unit in the donor pool, ranked by magnitude. The RMSPE of the oil-producing region is by far larger than every RMSPE of the donor pool units. Thus, the estimated effect is considered *statistically significant*. Sources: *Encuesta Nacional de Ocupación y Empleo* (ENOE) by *Instituto Nacional de Estadística y Geografía* (INEGI).

examines the impact of energy price booms and busts in local economies in Western Canada with a difference-in-differences strategy. He finds negative effects on the labor market due to price busts across many (but not all) sectors.

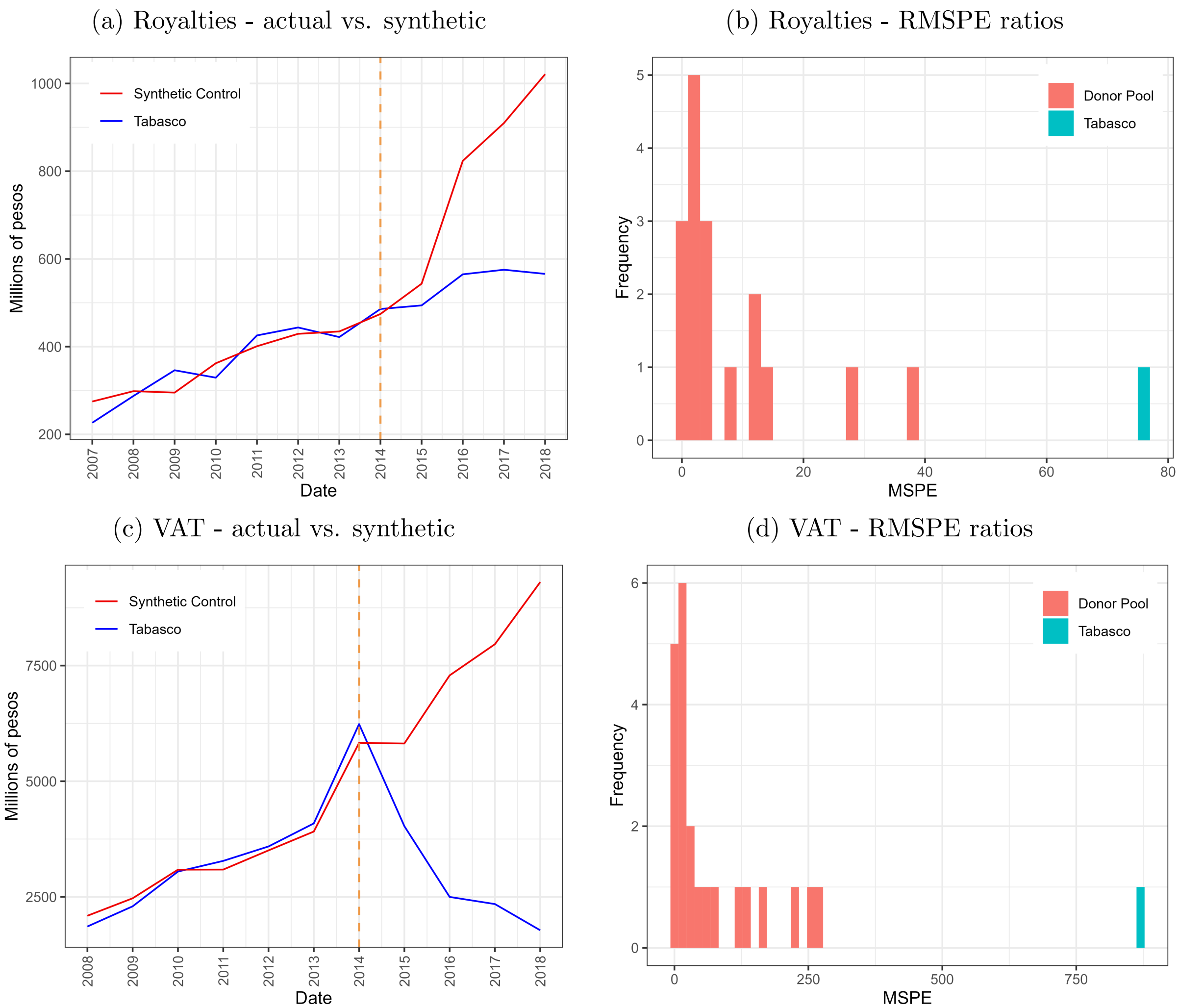
4.2 Fiscal effects

Let us now discuss the fiscal effects of the oil price bust. For these outcomes, we will focus on the state of Tabasco. We do this because Tabasco is the state where oil production as a share of output is, by far, the biggest. This makes it possible to detect the effect of the price shock on government revenues with the synthetic control technique. This results from two main factors. 1) Data limitations: the revenue data is provided annually, giving fewer data points to construct the synthetic control. 2) Mathematical limitations: governments do not tax 100 percent of economic activity, so as the importance of oil output in an economy decreases, detecting impacts that correspond to a share of the effect on the overall economy becomes problematic.

Figure 6 shows the oil price shock effects on two revenue types. Panels (a) and (b) display the impact on royalties charged to public-domain goods. These are collected directly by state governments. They are defined as a fixed amount based on public-domain good quantities. As oil is a public-domain good, its production is subject to the payment of royalties. Panel (a) shows that observed and synthetic royalties collected by Tabasco move similarly before the oil price bust. After the shock, we see a decrease in actual royalties while synthetic royalties continue upward. The estimated difference between Tabasco's actual and synthetic royalties amounts to a 28 percent decrease in collected royalties in the post-oil-price bust period. Thus, the evidence suggests a quite sizable negative effect on the local source of revenue most linked to oil production.

Panels (c) and (d) relate to the value-added tax (VAT) collected by the federal government in Tabasco's territory. The VAT is not directly pegged to oil production. It is charged on most intermediate and final goods traded in the economy. So, if economic activity decreases, VAT collection will most likely fall. This is indeed what we see in Panel (c) of Figure 6.

Figure 6: Effect of the oil price shock on revenues



Note: Panels (a) and (c) depict the realized trajectories of royalties and VAT in the Mexican oil region, together with the estimated synthetic control trajectories. Panels (b) and (d) show the RMSPE associated with the gap in panels (a) and (c) and the placebo estimates, ranked by their magnitude. The RMSPEs associated with the oil region's estimated royalties and VAT gaps are the largest among the estimated placebo gaps and, thus, considered *statistically significant*. Sources: *Anuario Estadístico y Geográfico por Entidad Federativa* and *Estadística de las Finanzas Públicas Estatales y Municipales* (EFIPEM) by *Instituto Nacional de Estadística y Geografía* (INEGI).

Actual and synthetic VAT revenue moved similarly before the price bust. However, we see a collapse in actual VAT revenue after the shock, while synthetic VAT continues to grow. The estimated difference between Tabasco's actual VAT and the synthetic VAT amounts to a 50 percent decrease in the post-price bust period. So, we find strong evidence that the drastic fall in economic activity caused by the oil price shock is followed by a severe contraction of government revenues, both for revenues directly linked to oil production and those related to the broader trade of goods in the economy.

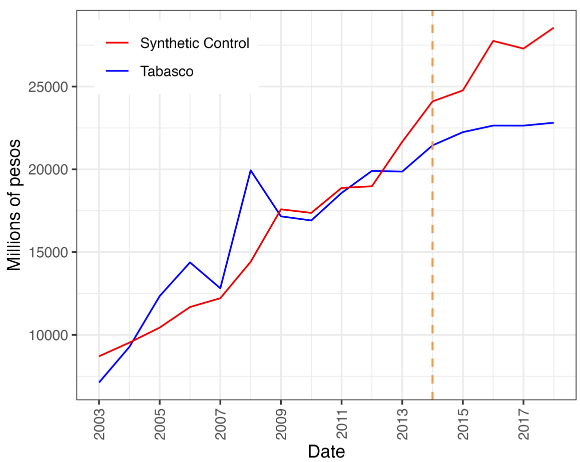
This revenue contraction plausibly leads to a decreased state capacity to provide public services and counteract the negative shock caused by the oil price bust. Fiscal transfers from the federation to Tabasco could halt this vicious circle. However, as discussed in Section 2.2, federal transfers to state governments are determined by formulas that depend positively on local economic activity. Thus, the legal framework implies that federal transfers to Tabasco should *decrease* following the 2014 oil-price bust. We test this empirically in Figure 7. Panel (a) and (c) show some evidence of a decrease in earmarked and non-earmarked federal transfers compared to the synthetic counterfactual. However, the RMPSE rank in Panels (b) and (d) corresponds to a non-statistically significant pseudo-p-value.

Therefore, we do not find a precise estimator even if we have some suggestive evidence of a decline in federal transfers following the economic shock caused by the price bust, compared to the counterfactual. Equally important, our estimations imply that there was no countercyclical response in the form of federal transfers to improve Tabasco's stance. This is remarkable as, in Mexico, federal transfers are state governments' primary source of revenue. Federal transfers represent around 80 of Tabasco's state government revenues (IMCO, 2022).

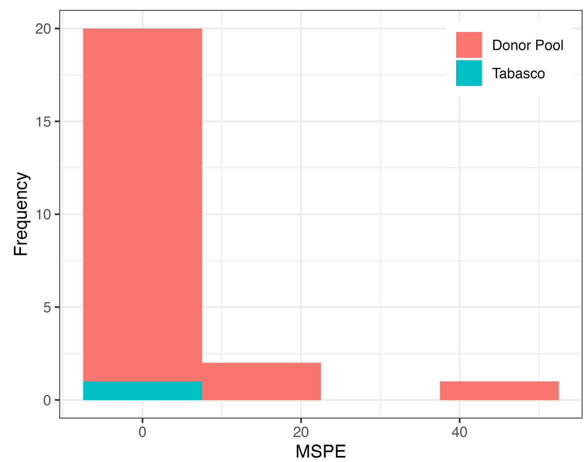
To sum up, the evidence indicates that the oil price bust had a large negative impact on Tabasco's economic output and labor market. A collapse in government revenues followed this. Moreover, there was no countercyclical fiscal federal transfer to counteract the negative shock. Most likely, this combination of factors left the local governments of an oil-producing economy with few tools to restart economic activity. This subnational government evidence differs from what previous literature finds at the national level. National governments in oil-

Figure 7: Effect of the oil price shock on federal transfers

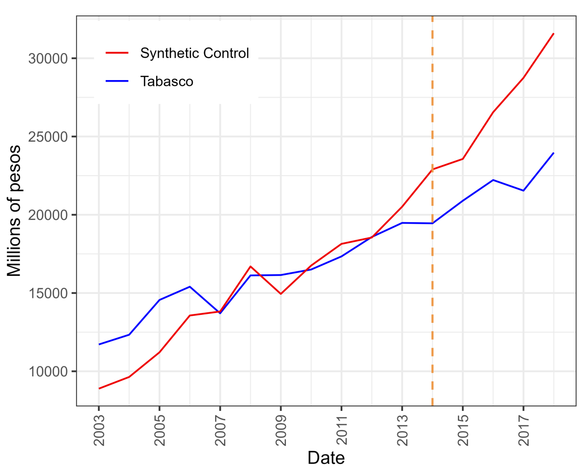
(a) Earmarked - Actual vs. synthetic



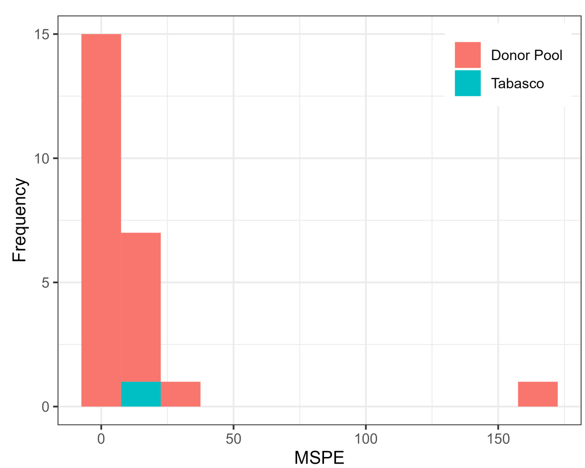
(b) Earmarked - RMSPE ratios



(c) Non earmarked - actual vs. synthetic



(d) Non earmarked - RMSPE ratios



Note: figure in Panel (a) depicts the realized earmarked transfers' trajectory in the Mexican oil region and the estimated synthetic control trajectory. Panel (c) depicts the same for non-earmarked transfers. Panels (b) and (d) show the RMSPE associated with the gaps in Panels (a) and (c), respectively, and the placebo estimates, ranked by their magnitude. The RMSPEs associated with the estimated transfers' gap for the oil region are not as extreme as some of the previous placebo RMSPEs and, thus, considered *statistically insignificant*. Sources: *Estadística de las Finanzas Públicas Estatales y Municipales* (EFIPEM) by *Instituto Nacional de Estadística y Geografía* (INEGI).

producing countries tend to soften the effect of oil price busts with fiscal buffers. Eltony and Al-Awadi (2001), Farzanegan and Markwardt (2009), and Arezki and Ismail (2013) provide evidence of countercyclical fiscal response to oil-price fluctuations in oil-producing national economies. Nusair (2016) finds that oil price busts do not consistently negatively affect the economies of oil-rich countries, likely due to fiscal buffers.

5 Conclusion

We provide strong evidence that the 2014 oil price bust caused an important deterioration of economic activity and labor outcomes in Mexico's subnational oil-producing economies. A collapse in fiscal revenues followed this economic decline, and federal transfers did not counteract this. These findings outline the importance of establishing fiscal buffers at the local level. This would give essential tools to subnational commodity-producing economies to face commodity price shocks. While oil-producing economies count on these buffers at the national level and regularly apply them, state governments do not count on them, resulting in high exposure to price busts.

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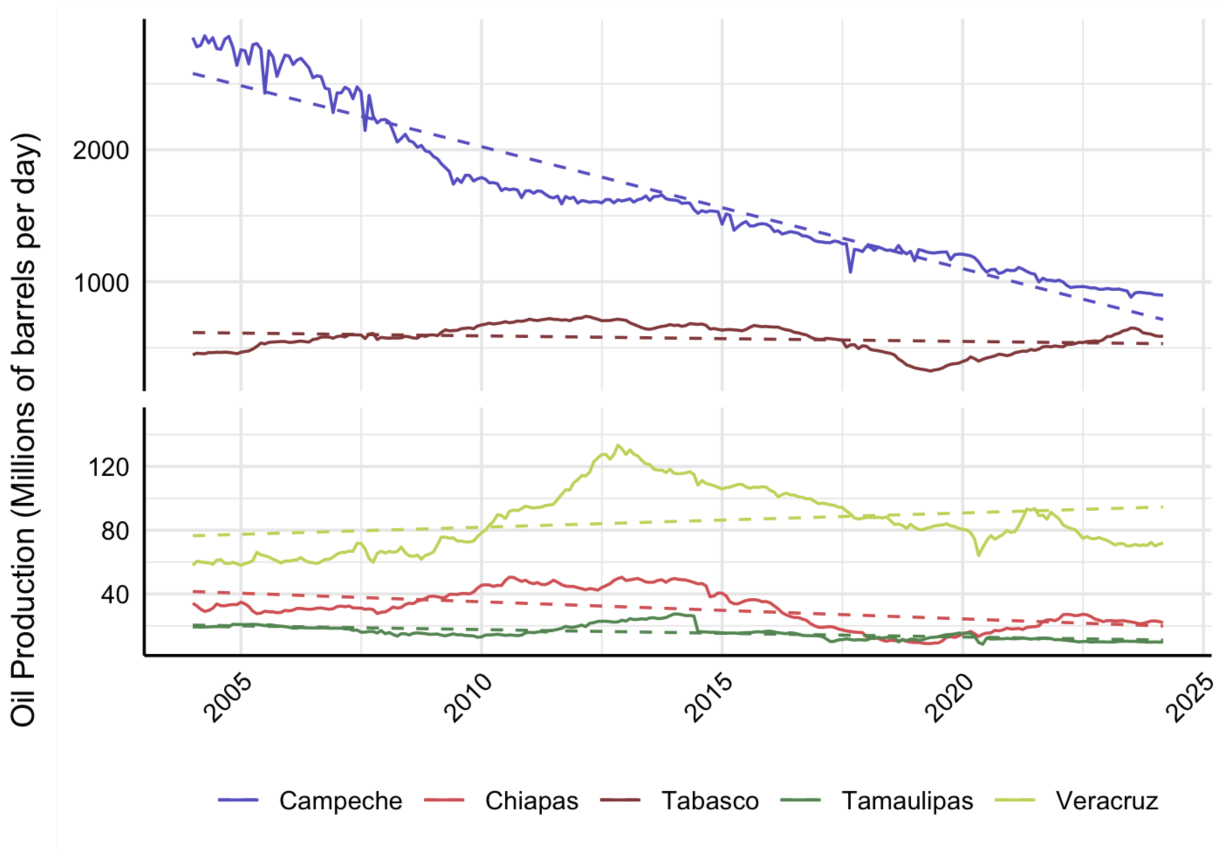
Appendix

A Additional Tables and Graphs

Figure A1: Oil-producing region

Note: This figure shows the four Mexican states in the oil region. From north to south: Tamaulipas, Veracruz, Tabasco, and Chiapas.

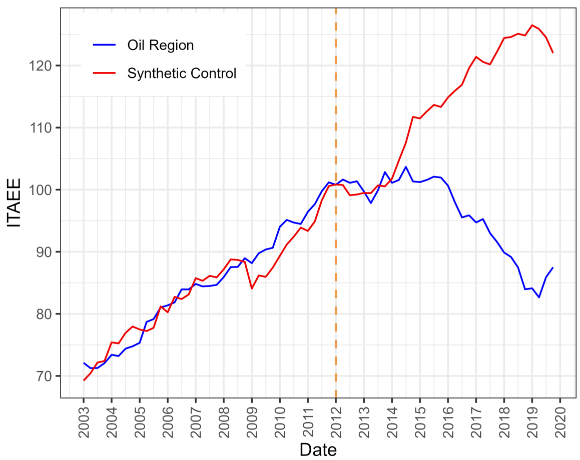
Figure A2: Oil output in important oil-producing states



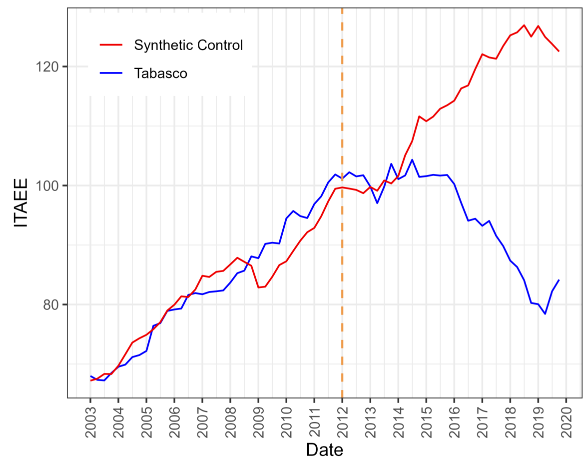
Note: This figure shows the oil production volumes in the four states in the Mexican oil region plus Campeche, traditionally an oil-producing state but with a declining production volume. Sources: *Sistema de Información de Hidrocarburos* by *Comisión Nacional de Hidrocaruros.*

Figure A3: Placebo test: shock in 2012 - ITAEE vs. synthetic ITAEE by state

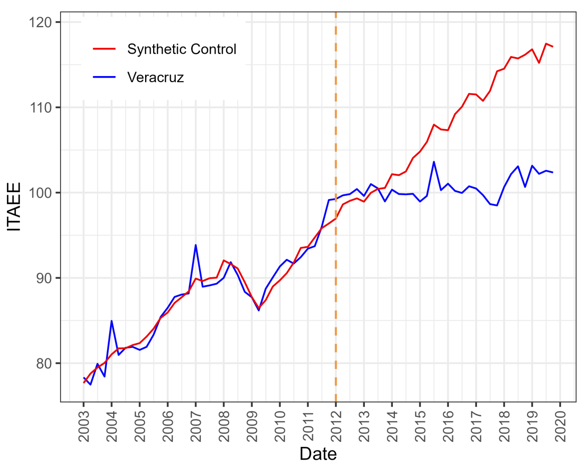
(a) Oil region



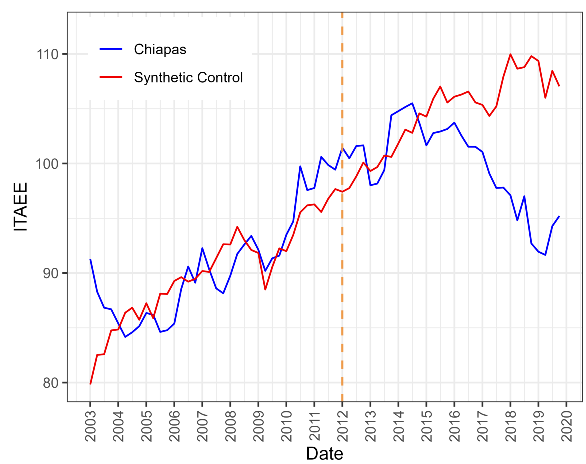
(b) Tabasco



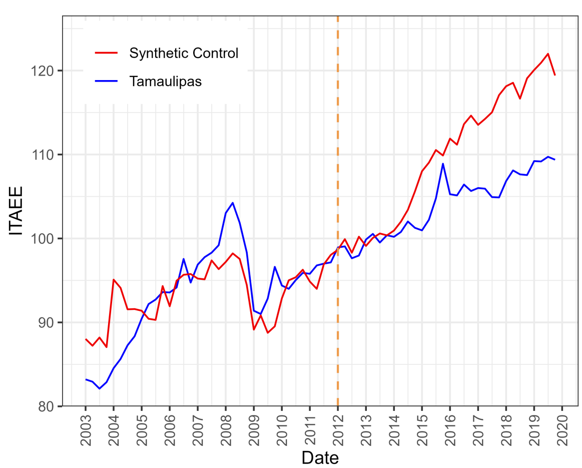
(c) Veracruz



(d) Chiapas



(e) Tamaulipas



Note: this figure shows the realized economic activity trajectory in the oil region and the four Mexican states that compose it separately, together with the corresponding estimated synthetic control trajectory. The synthetic control is constructed assuming the oil price bust occurred in 2012. Sources: *Indicador Trimestral de la Actividad Económica Estatal* (ITAEE) by *Instituto Nacional de Estadística y Geografía* (INEGI).

Table A1: Donor pool weights

State	ITAEE oil region	ITAEE Tabasco	ITAEE Chiapas	ITAEE Tamaulipas	ITAEE Veracruz	VAT Tabasco	Non earmarked transfers Tabasco	Earmarked transfers Tabasco	Royalties Tabasco	Employment oil region	Avg. labor earnings oil region
AS	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
BC	0.000	0.000	0.000	0.000	0.195	0.002	0.000	0.365	0.250	0.152	0.004
BS	0.000	0.000	0.000	0.000	0.000	0.444	0.000	0.000	0.369	NA	0.000
CM	0.000	0.000	0.000	0.000	0.264	0.089	0.000	0.000	NA	0.299	0.001
CH	0.000	0.000	0.000	0.244	0.000	0.001	0.000	0.000	0.001	0.001	0.001
DF	0.000	0.000	0.000	0.342	0.000	0.000	0.210	0.000	0.089	0.000	0.139
DG	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.085
GT	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.002	0.001
GR	0.000	0.000	0.545	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000
HG	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	NA	0.303	0.002
JC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.001
MC	0.000	0.000	0.105	0.000	0.000	0.001	0.000	0.096	0.001	0.183	0.102
MN	0.000	0.000	0.138	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.001
MS	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.000
NT	0.084	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.002	0.365
OC	0.000	0.000	0.212	0.000	0.085	0.000	0.000	0.000	0.000	0.001	0.000
QT	0.779	0.948	0.000	0.000	0.000	0.288	0.785	0.536	0.001	0.032	0.228
QR	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.001	0.063
SL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.278	0.001	0.000
SR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
TL	0.137	0.052	0.000	0.412	0.084	0.172	0.000	0.001	NA	0.009	0.004
YN	0.000	0.000	0.000	0.000	0.370	0.000	0.000	0.000	0.001	0.002	0.000
ZS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.002	0.001

Notes: this table shows the weight each state in the donor pool assigns to the synthetic control constructed under each outcome we present in the paper.