The Macroeconomic Impact of Fuel Price Controls and Excise Tax Subsidies in Mexico*

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Abstract

In 2022, the global economy faced an unprecedented energy-price shock, leading to a substantial surge in fuel prices. In this context, Mexico employed its excise tax framework to maintain local fuel prices below a reference price ceiling adjusted for inflation. This paper explores the evolution of this tax policy with a Dynamic Stochastic General Equilibrium (DSGE) model to assess its economic impact relative to alternative scenarios. The DSGE model integrates fuel usage in both household consumption and firms' production processes. Our analysis reveals that the price-smoothing mechanism effectively absorbs shocks and mitigates negative spillover effects on the broader economy, outperforming a government transfer program. However, prolonged and severe shocks impose considerable fiscal burdens, underscoring the necessity for alternative long-term strategies to decrease fuel dependency among households and firms.

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1 Introduction

In 2022, the global economy was hit by an energy-price shock that led to a sharp rise in fuel costs and contributed to soaring inflation rates worldwide. Governments in both advanced and emerging economies, including Mexico, responded with various measures such as subsidies, tax cuts, and direct transfers to alleviate the burden of rising energy prices on consumers. This paper presents a New Keynesian DSGE model specifically adapted to the Mexican economy to evaluate the effectiveness of these fiscal interventions in mitigating the impact of energy price shocks.

Mexico's flexible excise tax policy on retail fuel prices is designed to shield domestic consumers from the volatility of international fuel prices. This study examines the policy's effectiveness and its broader economic implications, including the potential outcomes in scenarios where such measures are not implemented. Our work offers a unique analysis of the evolution of Mexico's excise tax policy and its macroeconomic effects through the lens of a DSGE model. By providing a counterfactual analysis, we explore the consequences of removing the policy measures and the alternative use of government transfers.

We employ a closed-economy DSGE model that incorporates standard nominal frictions and price rigidities while also including fuel as a consumption good for households and as an input in production alongside labor and capital. The fiscal policy reaction function in our model is extended to include the stabilization of fuel prices as a policy objective, closely mirroring the existing Mexican fuel excise tax legislation. To account for the upper bound on domestic prices imposed by this policy, we adapt the model's solution accordingly. We then compare the effects of the policy measures on key economic variables under both scenarios —with and without the policy.

Our findings suggest that energy price-smoothing measures can effectively prevent major economic disruptions during fuel price shocks. The model successfully replicates observed household behaviors, such as reduced consumption of both fuel and non-fuel goods, increased labor supply, and higher savings through government bonds. It also captures firms' responses, including reallocating resources by substituting fuel with additional capital and labor. Moreover, the model highlights the divergence between monetary and fiscal policies: while monetary policy raises interest rates to combat inflation, fiscal policy increases transfers and investments to cushion the impact of the shock. This divergence intensifies fiscal pressures, leading to lower revenues, higher countercyclical spending, and increased debt-related costs, ultimately resulting in a larger fiscal deficit and debt accumulation.

When energy price shocks persist over extended periods, the fiscal burden can become substantial, underscoring the need for alternative strategies to maintain fiscal stability. Our welfare analysis reveals that price-smoothing measures are more effective than government transfer programs in managing shocks and preventing adverse economic outcomes.

The Mexican economy provides an ideal case study for assessing the significance of fuel prices. Regular gasoline holds the second-highest weight in the consumer price index, with spending on regular and premium gasoline accounting for about 6 percent of total household expenditures in 2022. Fuels also play a crucial role as an input in goods production. Despite efforts to improve efficiency and increase the use of renewable energy, Mexico's trade and transportation system remains heavily reliant on fuel-based transport —60 percent of all goods distributed in Mexico are transported by trucks, even over long distances where rail and maritime options could be more cost-efficient.

In contrast to many advanced economies, where energy price-containment measures have been largely temporary, Mexico —like other emerging market economies, particularly those that are oil producers— has a long-standing tradition of providing special fiscal treatment for fuel prices. This history offers a valuable perspective on how an emerging market economy like Mexico has managed fuel subsidies and tax cuts over the years. This paper leverages this historical context to provide insights into how the Mexican government has utilized excise taxes as a mechanism for price stabilization.

This paper contributes to several strands of literature. First, it extends the research on the economic impact of energy prices. Previous studies, such as Blanchard and Galí (2009) and Chen (2009), have documented the diminishing effects of oil price shocks on economic activity and inflation. However, these studies do not differentiate between oil and fuel price shocks. Recent research suggests that findings based on oil prices as an exogenous variable may not be applicable to those using fuel prices (Kpodar and Abdallah, 2017, Kpodar and Liu, 2022, Abdallah and Kpodar, 2023). This distinction is crucial because many governments, particularly in emerging economies, mitigate oil price shocks through fuel subsidies and other price control measures. For instance, Kpodar and Liu (2022), employing a local projections approach across European Union countries, finds significantly larger effects on inflation when retail gasoline prices, rather than oil prices, are used as the independent variable. While this does not negate the arguments that the impact of oil shocks on the economy has diminished due to factors such as improved monetary policy frameworks, reduced wage rigidity, and the declining importance of oil in consumption and production, it underscores the critical role of price-suppressing measures.

Our study also contributes to the literature on fuel price subsidies, which can be divided into two primary strands. The first focuses on quantifying the magnitude of these subsidies and their en-

vironmental implications (Coady, Flamini, and Sears, 2015, Black, Liu, Parry, and Vernon, 2023). Our paper adds to this body of work by estimating the fiscal cost of fuel price containment measures in Mexico over 30 years.

The second strand of research on fuel subsidies has gained renewed relevance in the context of the growing interest in fiscal policy and price controls as tools to combat inflation. For example, Dao, Dizioli, Jackson, Gourinchas, and Leigh (2023) examines unconventional fiscal measures in the European Union to contain energy prices between 2022 and 2023, concluding that while these measures effectively curb inflation, they also pose significant challenges to fiscal sustainability, particularly in response to more persistent price shocks. Auclert, Monnery, Rognlie, and Straub (2023) contrasts the effects of energy price shocks in standard representative-agent models versus heterogeneous agent models, showing that while energy price subsidies can mitigate shock effects within individual economies, they may also create negative externalities for other economies by reducing the global energy demand price elasticity.

Finally, our paper closely aligns with several case studies. Ozgur, Aydin, Karagol, and Ozbugday (2021) analyzes Turkey's fuel price stabilization system implemented in 2018, finding that the subsidy program reduces the pass-through effect of oil prices to inflation. Similarly, Dartanto (2013) examines Indonesia, using a Computable General Equilibrium Model, and finds that reducing fuel subsidies by 25 percent increases poverty incidence by 0.26 percentage points. However, reallocating the savings to public spending and transfers can neutralize or even reverse this adverse impact.

By expanding on these themes, our study provides a comprehensive view of the complex interplay between fuel price shocks, fiscal policies, and economic stability in an emerging market like Mexico.

2 A Brief History of the Fuel Excise Tax in Mexico (1980-2024)

Since 1994, the Mexican government has implemented a flexible taxation policy on retail fuel prices designed to shield domestic consumers from the volatility of international fuel prices. This policy leverages the excise tax as a buffer, adjusting the tax rate or providing subsidies to stabilize domestic fuel costs amidst global price fluctuations.

Over the years, this mechanism has undergone numerous changes, with each iteration sometimes sparking poignant criticism and political unrest after the price shocks. In this section, we chronicle the evolution of this policy over the past 43 years, highlighting the key changes. Additionally, we present a measure to quantify the financial impact of these policy adjustments on public finances, offering a comprehensive view of their economic implications.

Table 1. A Summary of Mexico's Excise Tax History

The Early Stage of the Mexican Fuel Excise Tax (1980-1993)
The Excise Tax Law is enacted in Dec-1980
Highly regulated fuel market with government-administered prices
Excise tax with an ad-valorem rate (a percent of the price)
No adjustment mechanism to the excise tax rate
The Era of Administered Prices (1994-2015)
Highly regulated fuel market with government-administered prices
Excise tax with an ad-valorem rate (a percent of the price)
Monthly adjustments to offset international price variations
The Transition to Fuel Price Liberalization (2016-2018)
Gradual process of market deregulation
Market prices and private participation (distribution)
Excise quotas in pesos per liter by fuel quality (octanes)
Ad-hoc adjustments of quotas (from Jan-2017 weakly adj.)
Balancing Fixed and Flexible Fuel Pricing Policies (2018-2024)
Excise quotas in pesos per liter by fuel quality (octanes)
Inflation adjustment of a base price to set a cap for international prices
Weakly adjustments of quotas based on a formula

2.1 The Early Stage of the Mexican Fuel Excise Tax (1980-1993)

In December 1980, the Mexican government enacted the Excise Tax Law, which imposed an ad valorem excise tax of 50 percent on low-octane gasoline and 138 percent on high-octane gasoline under Article 2. In December 1982, the law was amended to apply a uniform tax rate of 110

percent to both types of gasoline and diesel, which was newly included under the same article. From 1982 until 1993, no significant amendments were made to the law regarding fuel taxation[1].

During this period, the Mexican fuel market was heavily regulated. Gas stations were only permitted to sell gasoline under the Pemex brand, the state-owned enterprise, with prices set by the Mexican Ministry of Finance. Private participation was limited to Pemex franchises, which could generate profits through a fixed markup agreed upon with Pemex (Davis, Mcrae, and Bejarano, 2019). This market structure persisted with minimal changes until 2015.

Although data from this period is limited, we do know that motor vehicle use was not yet widespread across the country. In 1980, there were only 86 motor vehicles per 1,000 inhabitants, and by 1993, this number had risen to 135 —still well below international standards (e.g., in 1993, Spain had 341 vehicles per 1,000 inhabitants).

2.2 The Era of Administered Prices (1994-2015)

In December 1993, the Mexican government introduced some flexibility in the way that the excise tax rates were determined. Thereafter, instead of establishing a fixed excise tax rate, the government defined a monthly mechanism to adjust it. The new mechanism turned the excise tax into an endogenous result of the interaction between the international and the government-administered prices. When international prices were lower than the government-set prices, the excise tax rate was positive, allowing the government to collect the difference between the two prices. Conversely, if international prices exceeded government-administered prices, the government provided a subsidy to cover the price difference. Since the Ministry of Finance controlled domestic prices, this mechanism effectively meant that the government absorbed within its budget the financial losses or gains from fuel prices that did not fully reflect market conditions.

Over the years, the definition of international prices has played a major role in the history of the excise tax on fuels. In the Excise Tax Law, this concept is constructed from an international benchmark price, traditionally U.S. Gulf Coast fuel prices, converted to pesos, to which transportation costs, profit margins, tariffs, and other adjustments are added[2].

This mechanism, with slight modifications, was in force until the end of 2015. Throughout these years, the gasoline market remained under strict regulation. The advantage was clear: gaso-

[1] Unless otherwise specified, throughout the text, "fuels" refers to low-octane gasoline, high-octane gasoline, and diesel.

[2] In the Mexican legislation, it is usually referred to as the *reference price*, but we prefer the term international price to simplify the description.

line price inflation was stable over these years, with an average contribution of less than 0.3 percentage points to the headline inflation. Since the international price is converted into pesos at the prevailing exchange rate, the excise tax indirectly contained the exchange rate pass-through to domestic prices. However, the fiscal cost of preserving the administered prices started to pick up in the early 2000s with the oil prices and the rest of the commodity prices.

2.3 The Transition to Fuel Price Liberalization (2016-2018)

In December 2012, a new administration took office in Mexico with an agenda focused on market-oriented reforms, including a strategy to open fuel markets to private competition and gradually liberalize prices. A key aspect of this period was the commitment to ensuring that domestic fuel prices reflected international price movements after taxes.

In November 2015, the administration amended the Excise Tax Law, replacing the ad valorem tax rates on fuels with fixed quotas expressed in pesos per liter. Additionally, a floating-band system was introduced to gradually phase out price controls. Each month, the government would set a maximum price for fuels based on international price conditions, with these maximum prices required to fall within a predetermined range. The government maintained prices within this range by making monthly adjustments to the statutory excise tax quotas. If international prices fell below the range, it signaled an increase in the effective quotas. Conversely, if international prices exceeded the upper limit, the quota was reduced accordingly.

This system led to the existence of two quotas: the statutory quota, fixed by law, and the effective excise tax quota, which was the amount consumers actually paid at the pump. In 2016, the statutory quotas for regular, premium, and diesel gasoline were set at 4.2, 3.5, and 4.6 pesos per liter, respectively. However, the government reduced the quota several times throughout the year; on average, the effective excise tax quotas were 3.5, 2.7, and 4.8 pesos per liter. As a result, the government provided an average fiscal allowance of 70 and 80 cents for regular and premium gasoline but charged an additional 20 cents for diesel.

The Mexican government aimed to further deregulate prices by replacing the floating-band system in 2016 with a regional maximum price scheme as a step toward fully market-determined prices. This liberalization process was implemented sequentially in 2017 by geographic region, with the maximum prices replacing the floating band in states where prices had not yet been liberalized. The process began in the northern states near the U.S., where fuel market arbitrage

between the two countries has historically existed.[3] On March 30, 2017, prices were liberalized in two northwestern states (Baja California and Sonora). By June 15, liberalization extended to the remaining northern border states: Chihuahua, Coahuila, Nuevo León, and Tamaulipas. The process continued southward, and by November 30, all fuel prices across the country were determined by market conditions.

The shift from a price band system to a maximum price scheme on January 1st, 2017, marked a significant milestone in Mexico's fuel market history, leading to the largest fuel price increase ever recorded in the country. Prices surged from 14.3 pesos per liter on the last day of December 2016 to 16.5 pesos per liter on January 1st, representing a 15.8 percent increase in a single day. The ongoing state-by-state price liberalization throughout the year led to even higher fuel prices nationwide. By the end of 2017, annual inflation in the energy component reached 14.4 percent, with headline inflation at 6.8 percent, compared to 2.5 and 3.4 percent, respectively, a year earlier. This dramatic price increase caused consumer confidence to plummet by 18.4 percent —the largest contraction on record, surpassing the 8.7 percent drop during the 2009 Global Financial Crisis— and triggered widespread social unrest and demonstrations.

In response to the challenges of the price liberalization process, the government adjusted its approach by implementing temporary reductions to the statutory excise tax rate. The sharp rise in fuel prices in early 2017, along with the resulting social unrest, likely influenced the government's decision to grant discretionary tax cuts. These reductions were not based on a consistent methodology and were adjusted weekly. Every Friday, the government announced any changes to the fuel excise tax rates that would be in effect for the following seven days —a practice that continues to this day.

It wasn't until November 2017, after the deregulation process was completed that the government publicly disclosed the methodology for determining the weekly excise tax. This mechanism, which remains as a key element in the current legislation and is incorporated into the DSGE model developed in Section 3, involves constructing two prices: the international price and the base price. The international price refers to an international benchmark —traditionally U.S. Gulf Coast fuel prices— converted to pesos, with transportation costs, margins, taxes[4], and other adjustments added. The base price was defined as a smoothed series of the international price.

When the international price was less than or equal to the base price, the government collected the full statutory excise tax quota. However, if the international price exceeded the base price,

[3]The government has provided special tax treatment to municipalities near the U.S. northern border to prevent such arbitrages. More details can be found at Castillo (2022).

[4]These taxes include a carbon tax, a fixed state excise tax, and the VAT.

the government granted a temporary reduction in the excise tax rate, with the reduction amount dependent on the difference between the two prices —the greater the difference, the lower the effective excise tax rate. This mechanism helped to cap consumer price increases, particularly by smoothing the base price to prevent sharp spikes like those seen in early 2017.

Despite the volatility in prices and the accompanying social unrest, the retail gasoline market's structure improved compared to the previous highly regulated system, allowing for increased competition. In 2016, for the first time, private companies were granted permits to import fuel, and gas stations with brands other than Pemex were allowed to enter the market.

2.4 Balancing Fixed and Flexible Fuel Pricing Policies (2018-2024)

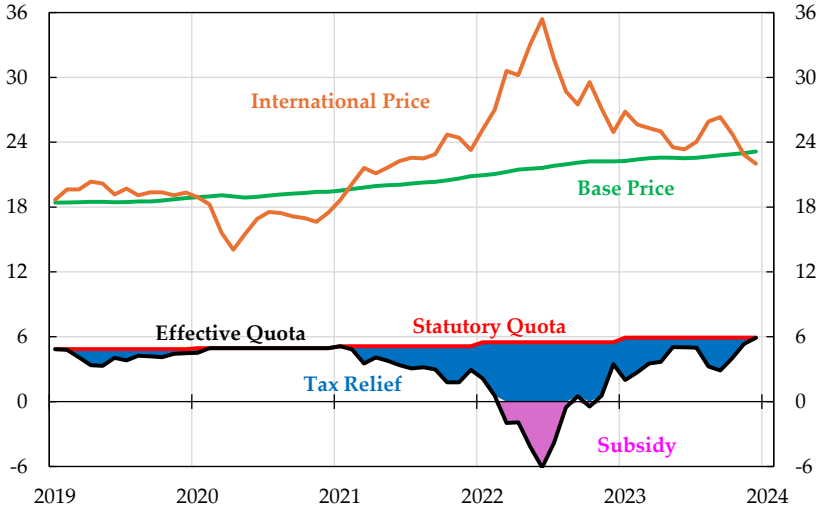
In December 2018, a new administration took office, propelled by a campaign focused on greater support for low-income households and the reversal of some reforms from the previous administration. The political party, along with the newly elected President, was highly critical of the fuel price hikes that occurred in 2017 and 2018.

Upon taking office, the new administration committed to preventing any real-term increases in fuel prices. The Ministry of Finance developed a mechanism to fulfill this pledge, which involved adjustments to the excise tax quota while avoiding a return to government-administered prices and implementing a major amendment to the Excise Tax Law. The weekly adjustments to the excise tax continued to be based on the difference between the international price and a "base price".

The primary difference from the previous administration lay in how the base price was defined. Under the new administration, the base price was set as the fuel prices observed on November 30th, 2018 —the day before the Presidential term began— updated by the headline inflation rate starting from the second half of November 2018. As explained in the previous section, this mechanism ensures that the base price acts as a ceiling for retail fuel price increases. Since the base price increases in line with inflation, retail fuel prices cannot rise in real terms. Figure 1 illustrates the mechanism (see Appendix A for details on the data used in the figure).

Figure 1. Avg. Fuel Price and Excise Tax Quotas

Pesos per liter



Note: The graph shows the weighted average (by fuel consumption) of the effective excise tax collected or subsidized (when negative) and the international and base prices of the three main types of fuel consumed in Mexico —namely Magna (87 octanes), Premium (93 octanes), and Diesel.
Source: Own calculations with data explained in the main text and Appendix A.

In 2022, this mechanism faced a significant challenge due to sharp increases in international fuel prices following the outbreak of the war between Russia and Ukraine. By March of that year, the gap between international and base prices had widened so much that even a complete reduction of the statutory quota was insufficient to curb domestic price increases, necessitating government intervention through additional subsidies to maintain price stability. During this period, oil prices surged by nearly 50 percent, reaching over 120 dollars per barrel at their peak. From March to August, the government provided subsidies through tax credits on Corporate Income Tax (CIT) and later on Value-Added Tax (VAT) to cover the shortfall (The area shaded in pink in the Figure 1). This marked the first instance since 2015 where subsidies were extended beyond excise tax quota reductions.

Compared to other emerging markets and advanced economies, Mexico managed to keep fuel price inflation low and avoid a significant spike in headline inflation. In 2022, Mexico's headline inflation was approximately 7.8 percent, which, although high, was significantly lower than the average inflation rate of around 9.6 percent across OECD countries. While the fiscal cost of these measures was high, it was still lower than in other historical periods. The success of this approach can be attributed to the flexibility of the mechanism, which allows for adjustments to prevent completely fixed domestic prices. However, history teaches us that while such short-term mechanisms

can be effective, they are not a panacea for persistent shocks and may hinder policies aimed at reducing fuel dependency in the long term.

2.5 A Summary of The Excise Tax Trade-Off

A review of the history of the excise tax reveals that the Mexican government has consistently faced a trade-off between price volatility and excise tax collection. To illustrate this, we compiled data from various sources. From 1997 to 2016, we gathered monthly fuel prices for regular and premium gasoline and diesel, as published by the Ministry of Energy. Since the government set prices, this dataset includes the elements that were considered in their determination, such as the excise tax charge per liter for each fuel type, margins, transportation costs, etc.

Since 2017, when the government ceased determining prices, we have relied on data from Mexico's Energy Regulatory Commission (CRE). The CRE has published national fuel prices, enabling us to extend our dataset to include monthly domestic prices for the three types of fuels from January 1997 to December 2023.

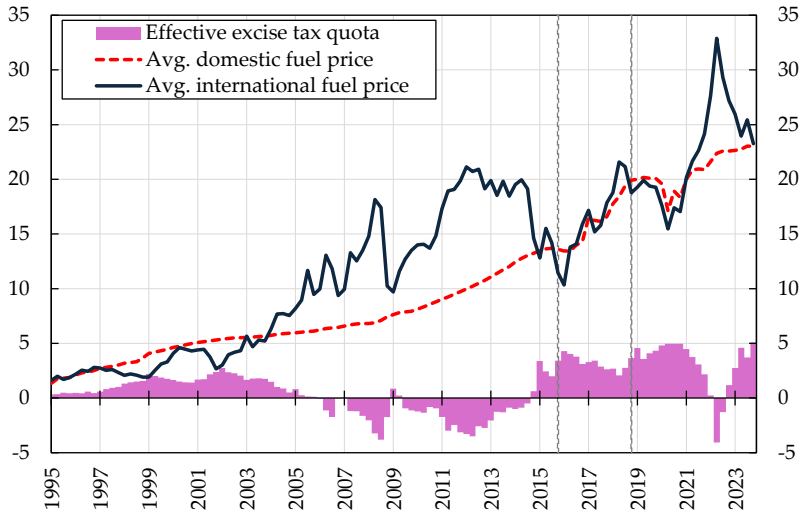
Moreover, since February 2017, the government has published weekly adjustments to the statutory excise tax quota for each fuel type in the Official Gazette of the Federation. These announcements, usually made early Friday mornings, detail the effective excise tax quota for the upcoming week. We compiled this information to create a daily dataset of the effective excise tax quotas from January 2017 to December 2023. By integrating this with the data from the Ministry of Energy, we have constructed a comprehensive monthly series of the effective excise tax quotas from January 1997 to December 2023.

To the best of our knowledge, this dataset represents the most comprehensive time series of fuel prices and excise taxes for the Mexican economy. In Figure 2, both the prices and the effective excise tax are presented as a weighted average based on consumption levels of the three fuel types. We utilized a five-year update window to reflect any changes in fuel consumption patterns accurately.

For further details on the data collection process, see Appendix A. In the appendix we also show how the data on the effective excise tax quota allow us to recover the official tax collection figures from the Ministry of Finance.

Figure 2. Avg. Fuel Prices and Effective Excise Tax Quotas

Pesos per liter



Note: The graph shows the weighted average (by fuel consumption) of international and domestic fuel prices for the types consumed in Mexico —-namely Magna (87 octanes), Premium (93 octanes), and Diesel-— and the effective excise tax collected or subsidized (when negative).
Source: Own calculations with data explained in the main text and Appendix A.

Our data set allows us to construct a measure of the impact of the excise tax policy on government finances. Our measure is based on current Mexican excise tax legislation. As detailed, since 2016, the Government has contained fuel price increases through temporary reductions in statutory excise tax quotas. When these quotas are fully exhausted, supplementary subsidies are provided to offset the price differential.

By comparing the effective excise quota with the statutory quota, which represents the potential revenue per liter of fuel, we assess the magnitude of the fuel price containment measure. Figure 3 illustrates this, breaking down the fiscal burden into two components: the opportunity cost of not collecting the full excise tax quota (tax relief) and the actual subsidies provided when the excise tax is exhausted. Subsidies are reflected as negative values of the effective excise tax quota.

Prior to 2016, Mexican legislation did not specify any excise tax quotas or a fixed ad valorem rate, resulting in no concrete measure of potential government revenue from the excise tax. To address this, we assumed that the maximum the government could have collected was the specific quota set in 2016, adjusted for inflation. By comparing the effective fuel excise tax quota with this hypothetical maximum, adjusted backward for inflation, we were able to estimate the fiscal support across the entire sample.

To calculate the aggregate fiscal cost of fuel price containment measures, we combined our data with fuel demand figures for Mexico. With information on the quantity consumed, the effective quota, and the statutory quota, we derived the values of tax relief and subsidies. These findings are illustrated in Figure 4.

From 1997 to 2002, the Mexican government collected revenues from the excise tax on fuels, approaching the potential maximum. However, as the commodity supercycle progressed, fuel prices increased, and the excise tax rate was gradually reduced. By February 2006, the tax rate turned negative for the first time, effectively becoming a subsidy. Apart from a few exceptions, the excise tax rate remained negative from 2006 to 2014, imposing a significant burden on public finances during President Felipe Calderon's administration and the early years of his successor's administration. Between 2007 and 2014, we estimate that the government spent nearly 1 percent of GDP per year on fuel price subsidies and potentially lost an additional 1.6 percent of GDP per year in foregone revenues.

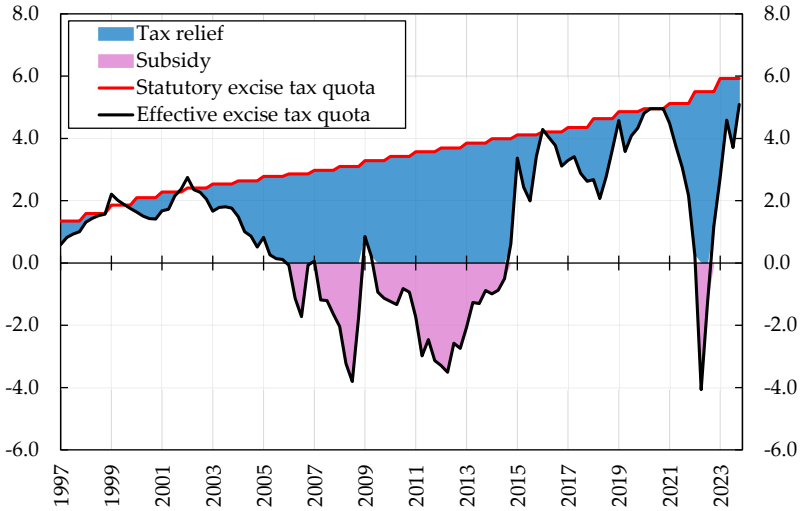
The collapse in commodity prices at the end of 2014 enabled the government to reinstate the excise tax fee. Consequently, between 2016 and 2018, the government collected higher excise tax revenues. This period also coincided with the process of market liberalization, which saw the largest increases in fuel prices and their volatility.

From 2018 to the present, the government has used the excise tax to prevent above-inflation increases in fuel prices. This mechanism allowed prices to fall with international declines but capped domestic price increases to inflation rates. In 2022, this mechanism was tested by sharp increases in international fuel prices following the outbreak of the war between Russia and Ukraine. In response, the government not only reduced the excise tax rate to zero but also provided additional subsidies beyond the statutory quota reductions, marking the first time since 2015 that such measures were taken.

From 1997 to 2023, the Mexican government's fuel price support imposed an average fiscal burden of 1.1 percent of GDP annually. This substantial expenditure prompts critical questions: Does this price smoothing mechanism truly benefit the economy, or does it impose greater costs than allowing market-driven price adjustments? Furthermore, could a targeted government transfer program yield better outcomes for households, public finances, and the broader economy? In the next section, we explore a comprehensive model to analyze the wider economic impacts of these mechanisms, offering insights that could reshape policy decisions.

Figure 3. Effective Fuel Excise Tax

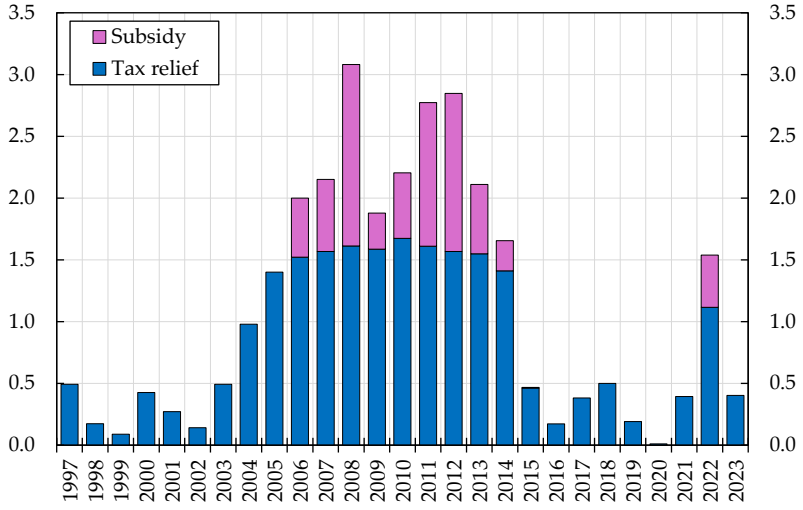
Pesos per liter



Note: The graph displays the weighted average (by fuel consumption) of the effective excise tax collected or subsidized (when negative) for the fuel types consumed in Mexico: Magna (87 octanes), Premium (93 octanes), and Diesel.
Source: Own calculations with data explained in the main text and Appendix A.

Figure 4. Excise Tax Cost

In percent of GDP



Note: The graph shows the total fiscal cost of the measures to contain fuel prices through excise tax adjustments.
Source: Own calculations with data explained in the main text and Appendix A.

3 A New Keynesian DSGE Model with Fuel

In this section, we develop a standard New Keynesian DSGE model tailored to the Mexican economy to illustrate the transmission of fuel price shocks. Our analysis includes both monetary and fiscal policy responses, specifically highlighting the excise tax adjustment mechanism in the Mexican tax code. By simulating price shocks akin to those experienced between 2009-2014 and 2021-2023, we show their potential economic impacts and explore scenarios without the tax mechanism. Our closed economy model incorporates standard nominal frictions and price rigidities while uniquely accounting for fuel as both a household consumption good and a production input alongside labor and capital. This approach allows us to capture the dual role of fuel in the economy, providing a more comprehensive analysis.

Understanding the impact of fuel price shocks on the economy is crucial for policy-making, given Mexico's significant reliance on fuel for both household transportation and the often-overlooked dependence on fossil fuel-powered trucks for merchandise and food distribution. Our findings aim to inform fiscal and monetary policies, providing insights into the effectiveness of the current tax mechanism and exploring potential alternatives. We outline the primary features of the model in this section, with detailed explanations and estimations provided in the appendices.

3.1 Households

We set a representative household with a continuum of members indexed by $j \in [0,1]$. Each household decides at the time how much consumption (C_t), labor supply (L_t), and capital expenditure on the next period (K_{t+1}) will allocate to maximize their expected present discounted value of the following utility function:

$$\mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \left(\frac{C_{t+i}^{1-\sigma} - 1}{1-\sigma} - \frac{L_{t+i}^{1+\eta}}{1+\eta} \right). \tag{3.1}$$

The household aggregate consumption C_t is a bundle of non-fuel goods (C_{N}) and fuel consumption (C_{E}) that represent a share ν in the whole consumption bundle. We assume that this bundle is a CES function with an elasticity of $\vartheta > 0$.

$$C_t = \left[(1-\nu)^{\frac{1}{\vartheta}} C_{\mathrm{N},t}^{\frac{\vartheta-1}{\vartheta}} + (\nu)^{\frac{1}{\vartheta}} C_{\mathrm{E},t}^{\frac{\vartheta-1}{\vartheta}} \right]^{\frac{\vartheta}{\vartheta-1}}. \tag{3.2}$$

The consumption of non-fuel goods has an aggregation function that accounts for a variety of goods $i \in [0,1]$ and elasticity of substitution $\xi > 1$:

$$C_{\mathrm{N},t} = \left(\int_0^1 C_{\mathrm{N},t}(i)^{\frac{\xi-1}{\xi}} di \right)^{\frac{\xi}{\xi-1}}. \tag{3.3}$$

The household optimization problem is subject to a traditional capital accumulation rule of motion (3.4) and a budget constraint (3.5).

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{3.4}$$

$$(1+\tau_{\mathrm{C}})P_{\mathrm{N},t}C_{\mathrm{N},t} + P_{\mathrm{E},t}C_{\mathrm{E},t} + P_t I_t + B_t = (1-\tau_{\mathrm{L}})W_t L_t + R_t K_t + R_{\mathrm{B},t-1}B_{t-1} - \mathrm{TR}_t + \Gamma_t. \tag{3.5}$$

Here I_t is the investment expenditure on capital goods (K_t) that depreciate with a δ rate. P_t is the general price level, while W_t and L_t are the nominal wage income and labor hours supplied, respectively. Finally, R_t is the rate of return on capital, and Γ_t are the net profits to the household from the ownership of firms. The Government taxes consumption and wage income with a VAT fixed rate of τ_c, and a payroll tax rate of τ_L; also, it uses net transfers (TR) and debt issuance (B) to smooth the business cycle and finance its budget deficits. The government's debt pays an interest rate of R_{B}. Later, in Section 3.4, we'll explain how these variables are used to set the fiscal and monetary policy.

The households also need to optimize their consumption of individual non-fuel goods ($C_{\mathrm{N},t}$) as well as the fuel goods ($C_{\mathrm{E},t}$) with the following setup.

$$\begin{aligned} \min_{C_{\mathrm{N},t}, C_{\mathrm{E},t}} \quad & P_{\mathrm{N},t}C_{\mathrm{N},t} + P_{\mathrm{E},t}C_{\mathrm{E},t}, \\ \text{s.t.} \quad & \left[(1-\nu)^{\frac{1}{\vartheta}} C_{\mathrm{N},t}^{\frac{\vartheta-1}{\vartheta}} + (\nu)^{\frac{1}{\vartheta}} C_{\mathrm{E},t}^{\frac{\vartheta-1}{\vartheta}} \right]^{\frac{\vartheta}{\vartheta-1}} \geq C_t. \end{aligned}$$

The results of this optimization problem lead to the individual goods demand functions and the general price index of the consumption goods once the optimal demands are substituted into the consumption constraint. It's worth noting that the non-fuel prices ($P_{\mathrm{N},t}$) are set endogenously within the model, while the fuel prices ($P_{\mathrm{E},t}$) are set partially by an exogenous price from international market and a fiscal tax/subsidy rule that smooths the fuel price shocks —a detail explanation

will be given on Section 3.3. The demand equations and price level are the following:

$$C_{\mathrm{N},t} = (1-\nu)\left(\frac{P_{\mathrm{N},t}}{P_t}\right)^{-\vartheta} C_t, \tag{3.6}$$

$$C_{\mathrm{E},t} = (\nu)\left(\frac{P_{\mathrm{E},t}}{P_t}\right)^{-\vartheta} C_t, \tag{3.7}$$

$$P_t = \left[(1-\nu)P_{\mathrm{N},t}^{1-\vartheta} + (\nu)P_{\mathrm{E},t}^{1-\vartheta}\right]^{\frac{1}{1-\vartheta}}. \tag{3.8}$$

Finally, the household optimization problem of consumption and labor gets the standard labor supply equation and the inter-temporal substitution of consumption equation (Euler equation):

$$\frac{W_t}{P_t} = L_t^{\eta} C_t^{\sigma}, \tag{3.9}$$

$$\left(\frac{\mathrm{E}_t C_{t+1}}{C_t}\right)^{\sigma} = \beta\left[(1-\delta) + \mathrm{E}_t \frac{R_{t+1}}{P_{t+1}}\right]. \tag{3.10}$$

3.2 Wholesale and Retail Firms

As in a traditional New Keynesian DSGE model, the optimization of firms occurs in three stages. In the first stage, an infinite set of monopolistic wholesale firms produce an intermediate good with identical production functions, aiming to maximize profits given the cost of production inputs. In the second stage, an infinite set of competitive retail firms determine the quantity of the intermediate goods demanded to transform it into differentiated final goods for sale to households. In the final stage, these retail firms set the optimal prices of the final goods on a staggered basis according to the Calvo Rule, introducing price stickiness and influencing inflation dynamics.

To analyze the effects of fuel price shocks on this economy, we introduce fuel as an additional factor in a Cobb-Douglas production function for intermediate goods. We assume, like in the previous section, that the price of fuel is an exogenous price set and imported from the international market with a special fiscal excise tax/subsidy rule applied to the retail price within this economy (see Section 3.3).

The representative monopolistic wholesale firm maximizes its profits, (Γ_t), given a production function, cost of inputs, and the good's price. The firm's output (Y_t) is a constant-return-to-scale function dependent on its demand for private capital (K_t), labor hours (L_t), energy from imported fuel (E_t), government capital $(K_{\mathrm{G},t})$, and the usual aggregate productivity disturbance (A_t). The productivity disturbance is defined as $A_t = A_{\mathrm{SS}}^{1-\rho_{\mathrm{A}}} A_{t-1}^{\rho_{\mathrm{A}}} \varepsilon_{\mathrm{A},t}$, where $\varepsilon_{\mathrm{A},t}$ is an exogenous shock i.i.d

$N(0,\sigma_{\mathrm{A}})$. The firm's maximization problem is:

$$\begin{aligned}&\Gamma_t = P_{\mathrm{N},t}Y_t - W_tL_t - R_tK_t - P_{\mathrm{E},t}E_t,\\ &\text{where } \; Y_t = A_tK_t^{\alpha_{\mathrm{K}}}L_t^{\alpha_{\mathrm{L}}}E_t^{\alpha_{\mathrm{E}}}K_{\mathrm{G},t}^{\alpha_{\mathrm{G}}}.\end{aligned}$$

The solution to this problem provides the input demand functions in terms of production and marginal cost:

$$K_{i,t} = \frac{\alpha_{\mathrm{K}}\mathrm{MC}_tY_{i,t}}{R_t}, \tag{3.11}$$

$$L_{i,t} = \frac{\alpha_{\mathrm{L}}\mathrm{MC}_tY_{i,t}}{W_t}, \tag{3.12}$$

$$E_{i,t} = \frac{\alpha_{\mathrm{E}}\mathrm{MC}_tY_{i,t}}{P_{\mathrm{E},t}}. \tag{3.13}$$

From the optimization problem, one can deduct the total cost ($\mathrm{TC}_{i,t}$) and the marginal cost ($\mathrm{MC}_{i,t}$) functions by substituting the optimal input's demands into the production function.

$$\frac{\partial \mathrm{TC}_{i,t}}{\partial Y_{i,t}} = \mathrm{MC}_{i,t} = \left(\frac{R_t}{\alpha_{\mathrm{K}}}\right)^{\alpha_{\mathrm{K}}}\left(\frac{W_t}{\alpha_{\mathrm{L}}}\right)^{\alpha_{\mathrm{L}}}\left(\frac{P_{\mathrm{E},t}}{\alpha_{\mathrm{E}}}\right)^{\alpha_{\mathrm{E}}}\frac{1}{A_tK_{\mathrm{G},t}^{\alpha_{\mathrm{G}}}}. \tag{3.14}$$

Then, a continuum set of retail firms indexed by $j \in [0,1]$ decides optimally how much non-fuel goods they are going to demand from the wholesale firms to transform and sell to the households. To aggregate the production, we use a Dixit-Stiglitz function.

$$\begin{aligned}&\max_{Y_{j,t}} \; P_{\mathrm{N},t}Y_t - \int_0^1 P_{\mathrm{N}(j),t}Y(j)_t\,dj,\\ &\text{where } \; Y_t = \left[\int_0^1 Y(j)_t^{\frac{\varphi-1}{\varphi}}\,dj\right]^{\frac{\varphi}{\varphi-1}}.\end{aligned}$$

The result from the optimization leads to the demand function for each firm, which is directly proportional to the aggregate demand and inversely related to the relative price, with an elasticity of substitution equal to φ.

$$Y(j)_t = \left(\frac{P_{\mathrm{N}(j),t}}{P_{\mathrm{N},t}}\right)^{-\varphi}Y_t. \tag{3.15}$$

By substituting the demand function into the Dixit-Stiglitz aggregation function, one gets the aggregate price for non-fuel goods.

$$P_{\mathrm{N},t} = \left[\int_0^1 P_{\mathrm{N}(j),t}^{1-\varphi} dj \right]^{\frac{1}{1-\varphi}} \tag{3.16}$$

Finally, in each period, a fraction θ of the firms, randomly selected, decide to change their prices on a staggered basis and independently of the time elapsed since its last price adjusted, according to the Calvo Rule in reference to Calvo (1983).

$$\max_{\widetilde{P}_{\mathrm{N}(j),t}} \; \mathrm{E}_t \sum_{i=0}^{\infty} (\beta\theta)^i \left(\widetilde{P}_{\mathrm{N}(j),t} Y_{j,t+i} - TC_{j,t+i} \right).$$

The optimization results yield the optimal price decision rule for each firm.

$$\widetilde{P}_{\mathrm{N}(j),t} = \frac{\varphi}{\varphi - 1} \mathrm{E}_t \sum_{i=0}^{\infty} (\beta\theta)^i MC_{j,t+i}. \tag{3.17}$$

From the previous result and using the aggregate price in equation (3.16) one gets the non-fuel price level for each period.

$$P_{\mathrm{N},t} = \left[\theta P_{\mathrm{N},t-1}^{1-\varphi} + (1-\theta) \widetilde{P}_{\mathrm{N}(j),t}^{1-\varphi} \right]^{\frac{1}{1-\varphi}}. \tag{3.18}$$

3.3 Fuel Market and Excise Tax/Subsidy

The international fuel price ($P_{\mathrm{E}_i,t}$) is set abroad in the global market and is subject to an exogenous shock $\varepsilon_{\mathrm{E},t} \sim N(0, \sigma_{\mathrm{E}})$. When the fuel is imported and converted its dollar price to pesos in the country, its price includes several additional components: transportation costs, margins, tariffs, storage, and a seller's markup, all aggregated into μ_{E}. The path of the international fuel price is influenced by its previous price, characterized by a persistence parameter ρ_{E}, relative to its steady-state ($P_{\mathrm{E}_i,s}$).

$$P_{\mathrm{E}_i,t} = \mu_{\mathrm{E}} \left(\frac{P_{\mathrm{E}_i,t-1}}{P_{\mathrm{E}_i,ss}} \right)^{\rho_{\mathrm{E}}} \varepsilon_{\mathrm{E},t}. \tag{3.19}$$

Each period, the fiscal authority applies a fixed excise tax quota (τ_{E}, in pesos per liter) and calculates the necessary tax or subsidy at the pump based on the international fuel price (P_{E_i}).

If the international price exceeds the base price ($\overline{P}_{\mathrm{E}}$), the excise tax ($T_{\mathrm{E}}$) is adjusted to subsidize the difference. Conversely, if the international price is below the base price, the fiscal authority imposes the full excise quota per liter.

$$T_{\mathrm{E},t} = \begin{cases} \tau_{\mathrm{E}} + \overline{P}_{\mathrm{E},t} - P_{\mathrm{E}_i,t}, & \text{if } P_{\mathrm{E}_i,t} > \overline{P}_{\mathrm{E},t} \\ \tau_{\mathrm{E}} & \text{if } P_{\mathrm{E}_i,t} \leq \overline{P}_{\mathrm{E},t}. \end{cases} \tag{3.20}$$

The fiscal authority updates the base price $\overline{P}_{\mathrm{E},t}$ with the general inflation rate (π_t) applied to the domestic fuel price in steady-state ($P_{\mathrm{E},ss}$) in logs: $\overline{P}_{\mathrm{E},t} = P_{\mathrm{E},ss} + \pi_t$. The purpose of this moving target is to smooth external shocks of fuel prices and limit the fuel demand when the general price level increases relative to the international fuel price. Accordingly, the domestic fuel price is set as follows:

$$P_{\mathrm{E},t} = T_{\mathrm{E},t} + P_{\mathrm{E}_i,t}. \tag{3.21}$$

As we describe in Section 2, this mechanism closely resembles the current excise tax policy in Mexico, implemented since 2018. This policy sets an upper bound on the domestic fuel price, which must be considered in the model's solution.

3.4 Government's Fiscal and Monetary Policy

Fiscal policy in this model has four key tasks: supporting the production of intermediate goods with public capital (K_{G}) accumulated through public investment (I_{G}); disbursing transfers (or collecting lump sum taxes) (TR) net to households to smooth consumption over the business cycle; issuing debt (B) and applying fixed tax rates ($\tau_{\mathrm{C}}, \tau_{\mathrm{L}}$) to finance expenditures; and using the excise tax (T_{E}, defined in equation 3.20) to stabilize exogenous fuel price shocks and collect additional tax revenues. While performing these tasks, fiscal policy must comply with Mexican fiscal rules, particularly the requirement to adjust expenditures to stabilize the debt-to-GDP ratio. The government budget constraint and the public capital law of motion are as follows:

$$B_t + \tau_{\mathrm{C}} P_{\mathrm{N},t} C_{\mathrm{N},t} + T_{\mathrm{E},t} C_{\mathrm{E},t} + \tau_{\mathrm{L}} W_t L_t = \mathrm{TR}_t + R_{\mathrm{B},t-1} B_{t-1} + P_t I_{\mathrm{G},t}, \tag{3.22}$$

$$K_{\mathrm{G},t+1} = (1-\delta) K_{\mathrm{G},t} + I_{\mathrm{G},t}. \tag{3.23}$$

The main fiscal expenditure policy variables I_{G} and TR respond to changes in the debt-to-GDP ratio as well as to exogenous shocks. In log-deviations from the steady state, the equations are the

following:

$$\widehat{I}_{\mathrm{G},t} = \gamma_{I_G}\widehat{I}_{\mathrm{G},t-1} - (1-\gamma_{I_G})\phi_{I_G}(\widehat{B}_t - \widehat{Y}_{t-1} - \widehat{P}_{t-1}) + \widehat{S}_{I_G}, \tag{3.24}$$

$$\widehat{\mathrm{TR}}_t = \gamma_{\mathrm{TR}}\widehat{\mathrm{TR}}_{t-1} - (1-\gamma_{\mathrm{TR}})\phi_{\mathrm{TR}}(\widehat{B}_t - \widehat{Y}_{t-1} - \widehat{P}_{t-1}) + \widehat{S}_{\mathrm{TR}}, \tag{3.25}$$

where each of the $\widehat{S}_{\{I_G,\mathrm{TR}\}}$ are the exogenous shocks i.i.d. $N(0,\sigma_{\{I_G,\mathrm{TR}\}})$. Note that these two variables have a persistent lagged component and an expenditure stabilization part that moves in the opposite direction with respect to the debt-to-GDP ratio. This specification has been used in the literature (Leeper, Plante, and Traum, 2010) and aligns with the Mexican Fiscal Responsibility Law. Specifically, the net transfers ($\widehat{\mathrm{TR}}$) and public investment ($\widehat{I}_{\mathrm{G}}$) ensure that the model complies with existing Law, adjusting fiscal shocks to maintain a stable debt-to-GDP path.

Meanwhile, the monetary policy sets the government's bond interest rate (R_{B}) to influence the general inflation rate through a traditional Taylor Rule. The Board of Governors at the Central Bank of Mexico (Banxico) has a single mandate to maintain the general inflation rate (π) at a 3 percent target. In addition to responding to inflation, the policy includes a parameter for the output gap (X) deviation from its steady state, influencing the monetary policy stance. A persistent component is also included to ensure gradual changes in monetary policy. This setup is consistent with the literature (Galí, 2008, Woodford, 2003). The monetary policy rule equation is as follows:

$$\frac{R_{\mathrm{B},t}}{R_{\mathrm{B,SS}}} = \left(\frac{R_{\mathrm{B},t-1}}{R_{\mathrm{B,SS}}}\right)^{\phi_{\mathrm{R}}} \left[\left(\frac{\pi_t}{\pi_{\mathrm{SS}}}\right)^{\phi_\pi}\left(\frac{X_t}{X_{\mathrm{SS}}}\right)^{\phi_{\mathrm{X}}}\right]^{1-\phi_{\mathrm{R}}} M_t, \tag{3.26}$$

where monetary policy can have persistent shocks that are influenced by $M_t = M_{\mathrm{SS}}^{1-\rho_{\mathrm{M}}} M_{t-1}^{\rho_{\mathrm{M}}} \varepsilon_{\mathrm{M},t}$, with $\varepsilon_{\mathrm{M},t}$ is an exogenous shock i.i.d $N(0,\sigma_{\mathrm{M}})$.

3.5 Market Equilibrium

To close the model, it is necessary to define the market equilibrium in the goods, labor, and capital markets, as well as the government budget constraint and resource allocation. The model's equilibrium consists of the following components:

- An exogenous fuel price (P_{E_i}) with a fiscal authority imposing an excise tax (T_{E}) to set the domestic fuel price (P_{E}). This influences endogenous prices such as wages (W), return on capital (R), domestic prices (P_{N}), and the interest rate on government bonds (R_{B}).

- Government interactions with households include net transfers (TR), bond issuance (B_t), and debt payments ($R_{\mathrm{B},t-1}B_{t-1}$). These transactions balance out without adding or subtracting resources from the economy.

- A production-possibility frontier described by the equilibrium condition of the goods market, where aggregate supply equals aggregate demand: $Y_t = C_t + I_t + I_{\mathrm{G},t}$.

We show in the Appendix B the steady-state solution and the log-linearization of the equations.

3.6 Model Estimation and Results

This section presents the results of our model estimation. We focus on the impact of fuel price shocks during the periods 2009-2014 and 2021-2023, comparing scenarios with and without the excise tax policy. Our findings indicate that the excise tax policy effectively mitigates the economic impact of fuel price shocks. The policy reduces the output gap, prevents significant increases in the general price level, and limits the rise in the monetary policy rate. In addition, it also results in less revenue lost and lower fiscal expenditures and deficits.

Our sample estimation goes from 2000 to 2018, capturing the behavior of variables before the new excise tax regime and avoiding extreme values during the Covid-19 recession. Table 2 presents the model parameters and their sources. Ten parameters are calibrated, and nineteen are estimated. The discount factor is calibrated at $\beta = 0.987$, implying an annual steady-state rate of 5.5 percent. The remaining calibrated parameters use data from the Economic Census, other surveys from the National Institute of Statistics (INEGI), and Mexico's Tax Code.

We estimate the rest of the model's parameters using a standard Bayesian approach for DSGE models (Smets and Wouters, 2007) after solving the steady state and log-linearizing the optimal equations presented in previous sections. The estimation procedure and data used are detailed in Appendix A. Our prior distributions generally match the posterior distributions, and our estimates align with existing literature for Mexico, such as Aguiar and Gopinath (2007), Fernández and Meza (2015), Boz, Durdu, and Li (2012), and McKnight, Mihailov, and Rangel (2020).

The baseline model is solved using a first-order linear approximation. However, the domestic fuel price policy includes two regimes, as shown in Section 3.3: one with a full excise tax and another with a partial tax or subsidy. Thus, the international fuel price occasionally triggers a binding constraint on the domestic fuel price.

To solve the model with this occasionally binding constraint, we use the piecewise solution proposed by Guerrieri and Iacoviello (2015). This solution is well-suited for the problem we

want to study since the model without the binding constraint has a rational expectation solution according to the Blanchard-Kahn condition, and the type of fuel price shocks, like the one that happened in 2022, was, in essence, temporal and unanticipated.

Table 2. Summary Table of Parameters

Symbol	Parameter Name	Value	Source
β	Subjective discount factor	0.99	Calibrated
ν	Energy consumption share by households	0.06	INEGI (2018)
δ	Capital depreciation rate	0.08	INEGI (2020)
α_K	Private capital share in prod. function	0.57	INEGI (2020)
α_L	Labor share in prod. function	0.27	INEGI (2020)
α_E	Energy share in prod. function	0.09	INEGI (2020)
α_G	Govt. capital share in prod. function	0.08	INEGI (2020)
τ_C	VAT rate	0.16	Tax code
τ_L	Tax rate on labor	0.35	Tax code
τ_E	Excise tax quota (pesos per liter)	5.51	Tax code
η	Inverse elasticity of labor supply	0.96	Estimated
σ	Intertemporal substitution elasticity	1.51	Estimated
θ	Calvo's fraction of firms not adjusting prices	0.79	Estimated
ϑ	Price-elasticity of consumption's demand	0.56	Estimated
φ	Elasticity of substitution of wholesale goods	1.05	Estimated
ρ_A	Productivity shock persistence	0.99	Estimated
ρ_E	Fuel price shock persistence	0.70	Estimated
μ_E	Energy price mean	1.53	Estimated
ρ_G	Govt. expenditure shock persistence	0.96	Estimated
ρ_{I_G}	Govt. investment shock persistence	0.51	Estimated
ρ_{TR}	Govt. transfers shock persistence	0.90	Estimated
γ_{I_G}	Govt. investment persistence	0.67	Estimated
γ_{TR}	Govt. transfers persistence	0.46	Estimated
ϕ_{I_G}	Govt. investment debt response	0.53	Estimated
ϕ_{TR}	Govt. transfers debt response	0.64	Estimated
ϕ_R	Monetary policy rule parameter on R	0.74	Estimated
ϕ_π	Monetary policy rule parameter on π	1.50	Estimated
ϕ_X	Monetary policy rule parameter on X	0.10	Estimated
ρ_M	Monetary policy shock persistence	0.35	Estimated

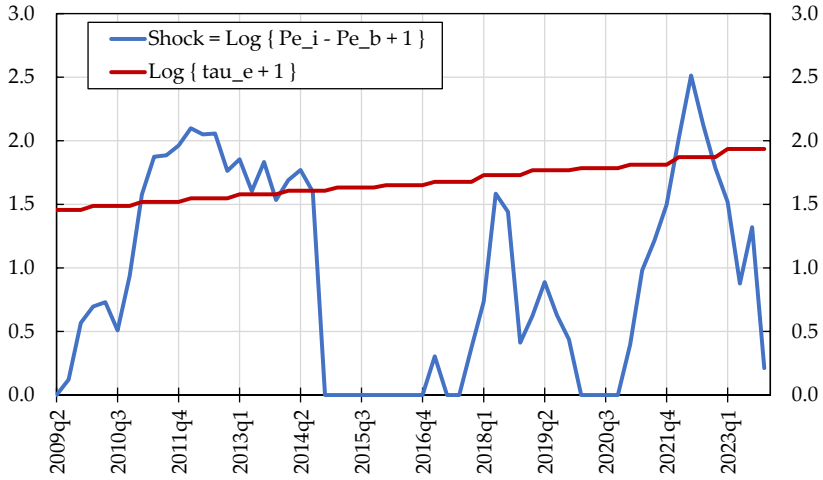
For the fiscal and monetary parameters, we highlight three important results. First, the estimations for fiscal equations align well with the observed behavior of fiscal policy in Mexico. Specifically, the expenditure shock persistence parameter for government net transfers ($\rho_{TR} = 0.90$) is significantly higher than that for public investment ($\rho_{I_G} = 0.51$). This difference reflects the greater rigidity in net transfers, indicating that these expenditures are less flexible and more stable over

time compared to public investment. Second, the adjustment parameter for the debt-to-GDP ratio is positive and notably higher for net transfers ($\phi_{TR} = 0.64$) than for public investment ($\phi_{I_G} = 0.53$). This result is consistent with the role of net transfers as a more important countercyclical stabilizer of the debt-to-GDP ratio in Mexico. It underscores that in times of economic downturn, net transfers are more responsive in helping to stabilize the debt-to-GDP ratio than public investment. Third, the parameters in the Taylor Rule are largely convincing, except for the output gap parameter ($\phi_X = 0.10$), which may not be different from zero, with the posterior distribution that includes this value within the distribution. This finding is consistent with the Central Bank of Mexico's single mandate of price stability. Moreover, since 2018, meeting minutes and rate decisions have indicated a strong focus on controlling inflation, leading us to assume that the output gap parameter, ϕ_X, is effectively zero. This assumption aligns with the Central Bank's priority of maintaining price stability over targeting the output gap.

We calibrate the duration and magnitude of fuel price shocks using historical data from Section 2, identifying two periods when the international price (P_{E_i}) exceeded the base price ($\overline{P}_{\mathrm{E}}$): 2009-2014 and 2021-2023. During these periods, the difference between international and base prices triggered excise tax relief, and subsidies began once the difference surpassed the quota. The domestic price fluctuated below the base price, which was in line with the international price at other times.

To model the fuel price shocks, we use the difference between the international price (P_{E_i}) and the base price ($\overline{P}_{\mathrm{E}}$) as the exogenous shock variable (see Figure 5). The base price serves as the benchmark for periods when the excise tax smooths the international price shocks. When the international price was above the base price, the excise tax started granting a tax relief, and when the difference exceeded the quota (red line), taxpayers received a price subsidy as a tax credit against the CIT and the VAT. For the 2017-2019 shock, when the international price was allowed to float, we projected the base price backward to estimate the shock's timing and size.

Figure 5. Fuel Price Shocks'



Notes: The graph shows the periods we identified the deviation of the international fuel price with respect to the base price that triggered the policy response from the fiscal authorities to start reducing the excise tax collection and, eventually, when the difference was higher than the quota (red line), the price subsidy began.

To show the impact of the price shocks, we first present the cumulative effects of the main variables in Table 3. This table provides a summary of the overall economic effects during the shock periods. Following the table, Figures 6, 7, 8, and 9 illustrate the impulse responses of the model, showing the deviation of each variable from its steady state.

In our analysis of the 2021-2023 and 2009-2014 events, we compare two distinct regimes: one with free-floating fuel prices and a non-binding policy constraint, where domestic prices increase in tandem with international prices, and another with a price subsidy and a binding constraint, where the excise tax is adjusted to keep domestic fuel prices aligned with the base price, thereby avoiding a full pass-through.

Our findings indicate that excise tax relief and subsidies effectively mitigate the magnitude of the shock and its subsequent effects on other macro and fiscal variables. Although excise tax revenue is reduced, and prices receive additional subsidies during these periods, public finances overall perform better. Specifically, tax revenue losses from consumption taxes are greater when fuel prices rise freely than when the excise tax mechanism contains them, as the full pass-through of the shock negatively impacts growth, consumption, and real wages.

The composition of excise tax losses differs significantly between the two scenarios. Under the free-floating regime, the excise tax quota remains constant throughout the shock, but fuel demand contracts significantly, leading to a reduction in tax revenues from fuel consumption. In contrast,

under the excise subsidy regime, the decline in fuel consumption is contained. However, once the quota is exhausted due to the price differential, the subsidy begins to erode tax revenues. As illustrated in Figures 7 and 9, the excise tax loss is slightly higher with the subsidy than without it. In the free-floating regime, the primary shortfall in revenues stems from reduced taxes on non-fuel consumption rather than from fuel itself.

On the expenditure side, fiscal countercyclical measures incorporated into the reaction functions lead to increased government transfers and public investment. These expenditures, combined with higher financial costs due to rising monetary policy rates and additional debt issuance to finance the growing deficit, result in a larger fiscal deficit and higher outstanding debt by the end of the shock period.

When examining key variables and overall effects, we estimate that from 2021 to 2023, the excise tax policy reduced the impact on the output gap by 0.6 percentage points, prevented a general price level increase of up to 4.4 percent, and avoided an additional 4.3 percentage point increase in the monetary policy rate at its peak (see Table 3). Similarly, during the 2009-2014 shock, the excise tax subsidy significantly mitigated the economic impact, with relief being greater due to the shock's extended duration from three to six years.

For the 2017-2019 shock, we estimate the effects using our model, although we acknowledge the absence of an explicit government policy to compare as an alternative. Additionally, the model is not fully equipped to accurately capture the behavior of economic agents following a change in the policy regime, as the fuel price shock occurred during the liberalization process. Nonetheless, when comparing the results to the model's steady state, we observe a negative economic impact. Specifically, the output gap averaged 0.6 percent below trend during the shock period, while the price level and the monetary policy rate increased by 1.9 percent and 1.6 percent, respectively. Beyond these key aggregates, other indicators such as non-fuel consumption, real wages, labor hours, and fuel prices were also adversely affected, highlighting the broad economic challenges posed by the shock.

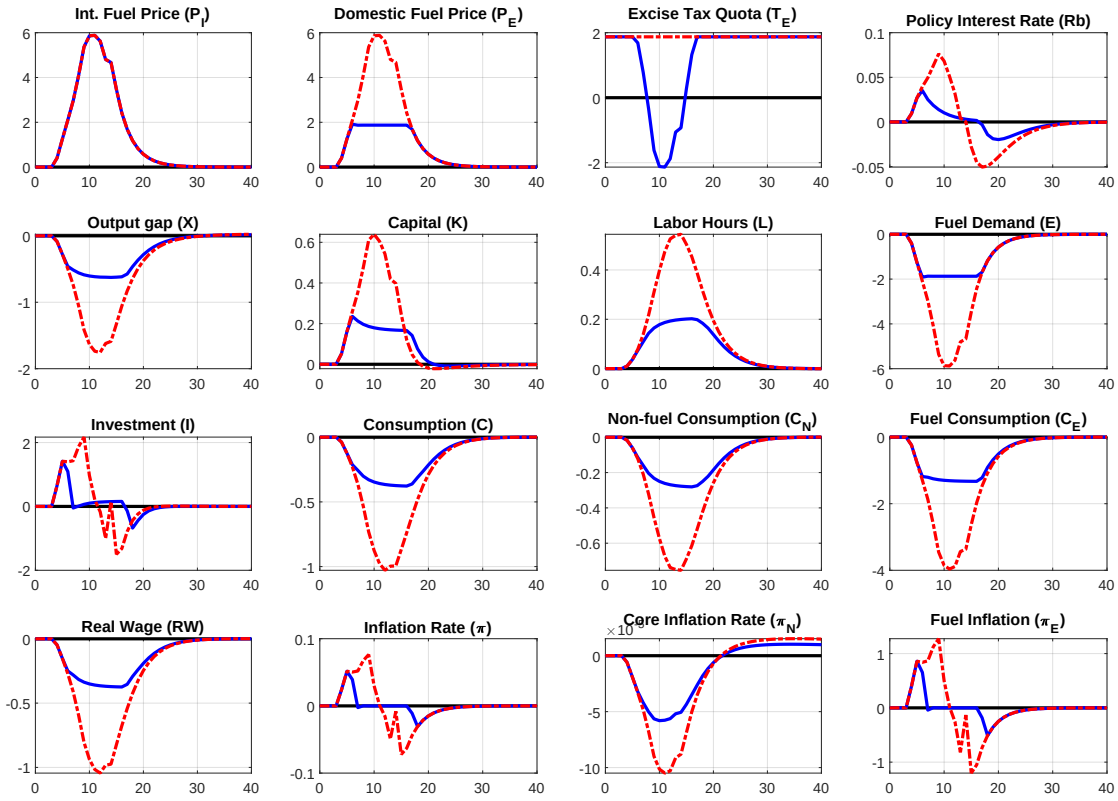
Overall, our analysis shows that the excise subsidy helps to smooth the economic impact rather than fully preventing the shock. Furthermore, the excise tax mechanism sustains higher prices when international fuel prices are low, only activating during significant price surges. The remainder of the paper shows that in an economy with high fuel dependence, price shocks are costly; however, policies like this can partially absorb the shock while supporting the transition to reduced fossil fuel dependence.

Table 3. Fuel Shock's Effect With and Without Excise Tax Subsidy

Variables	Shock Period		
	2021-2023	2017-2019	2009-2014
Excise tax (avg. $ per liter)			
With subsidy	1.0	-	0.3
Without subsidy	5.5	5.5	3.6
Output gap (avg. pp dif.)			
With subsidy	-0.5	-	-0.4
Without subsidy	-1.1	-0.6	-1.2
Price level (percent chg.)			
With subsidy	1.9	-	2.8
Without subsidy	4.4	1.9	8.4
Fuel price level (percent chg.)			
With subsidy	22.4	-	36.2
Without subsidy	57.5	22.0	146.7
Interest rate (at peak pp dif.)			
With subsidy	0.8	-	0.4
Without subsidy	5.1	1.6	5.4
Private cons. level (percent chg.)			
With subsidy	-3.4	-	-5.2
Without subsidy	-7.5	-3.3	-14.6
Private fuel cons. level (percent chg.)			
With subsidy	-13.0	-	-19.2
Without subsidy	-27.3	-12.8	-47.3
Real wage (percent chg.)			
With subsidy	-3.5	-	-5.3
Without subsidy	-7.8	-3.4	-14.9

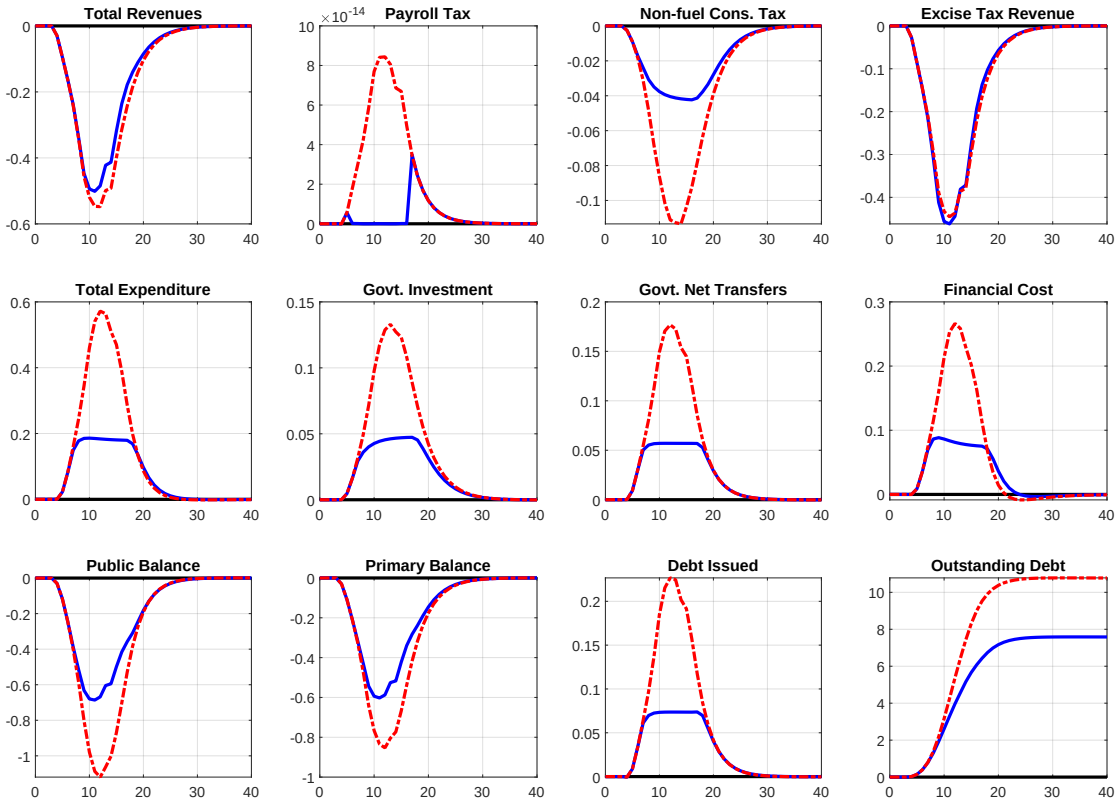
Note: The table shows the cumulative effect of the fuel price shock from the first quarter to the end of the period as percent deviations from the steady state, with the exception of the output gap and interest rate, which are in percentage points. The subsidy scenario applies the binding constraint (piecewise estimation), while the scenario without subsidy uses the non-binding constraint (linear estimation).

Figure 6. Impulse-Responses to the 2021-2023 Fuel Price Shock (Set 1/2)



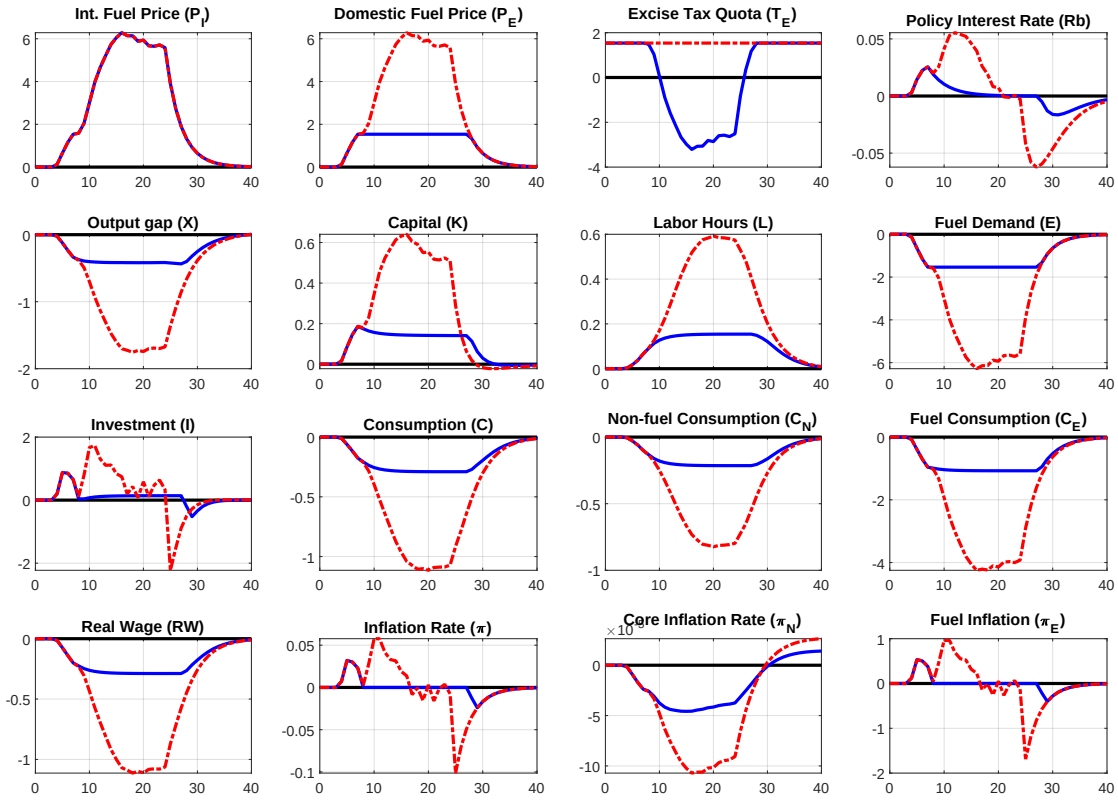
Note: For each variable, the x-axis represents time in quarters, and the y-axis shows the deviation of the steady-state from the international fuel price shock from 2021q1 to 2023q4. The red dashed lines show the counterfactual Linear model without the binding constraint of the fuel excise tax, while the blue line is the Piecewise estimation output with the binding constraint that put a cap to the international fuel price shock.

Figure 7. Impulse-Responses to the 2021-2023 Fuel Price Shock (Set 2/2)



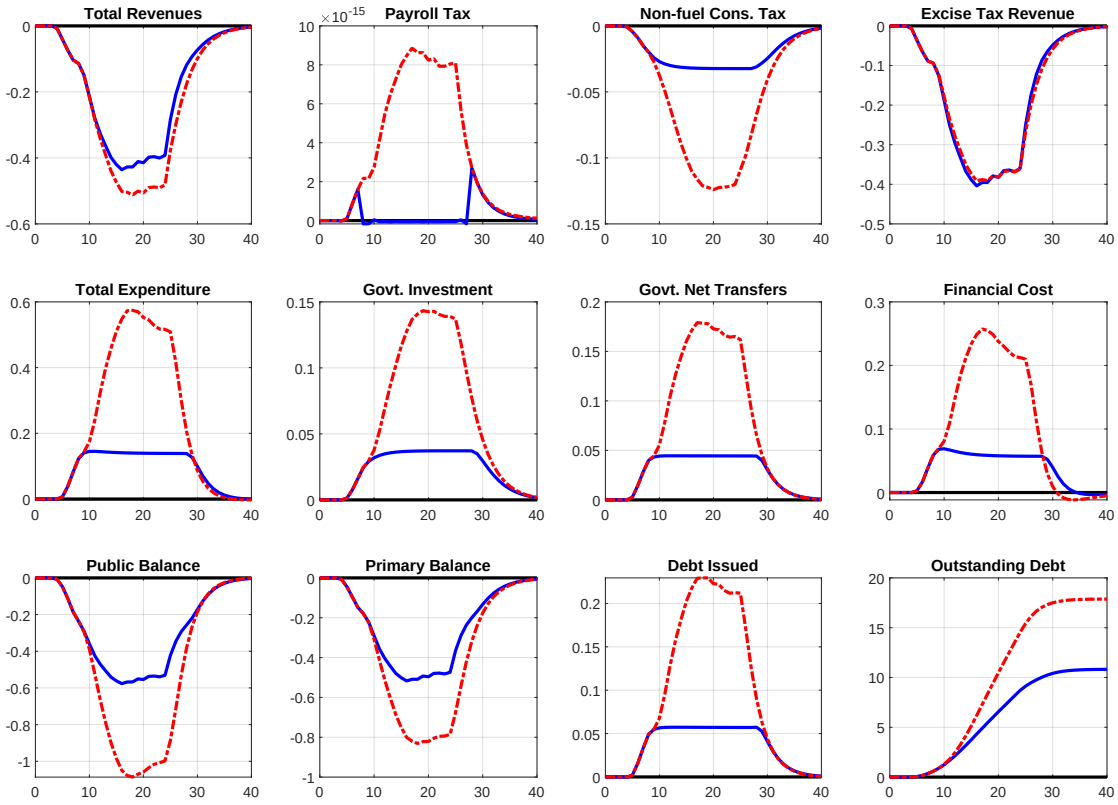
Note: For each variable, the x-axis represents time in quarters, and the y-axis shows the deviation of the steady-state from the international fuel price shock from 2021q1 to 2023q4. The red dashed lines show the counterfactual Linear model without the binding constraint of the fuel excise tax, while the blue line is the Piecewise estimation output with the binding constraint that put a cap to the international fuel price shock.

Figure 8. Impulse-Responses to the 2009-2014 Fuel Price Shock (Set 1/2)



Note: For each variable, the x-axis represents time in quarters, and the y-axis shows the deviation of the steady-state from the international fuel price shock from 2009q2 to 2014q3. The red dashed lines show the counterfactual Linear model without the binding constraint of the fuel excise tax, while the blue line is the Piecewise estimation output with the binding constraint that put a cap to the international fuel price shock.

Figure 9. Impulse-Responses to the 2009-2014 Fuel Price Shock (Set 2/2)



Note: For each variable, the x-axis represents time in quarters, and the y-axis shows the deviation of the steady-state from the international fuel price shock from 2009q2 to 2014q3. The red dashed lines show the counterfactual Linear model without the binding constraint of the fuel excise tax, while the blue line is the Piecewise estimation output with the binding constraint that put a cap to the international fuel price shock.

3.7 Transfers and Other Alternatives to Fuel Price Shock's Smoothing

In this section, we explore how policy alternatives, such as government transfers and reducing fuel dependence, can potentially lessen the impact of a fuel price shock. To evaluate these policy options, we establish a welfare framework, drawing on the approach used by Lester, Pries, and Sims (2014). We employ a compensating variation metric to compare welfare outcomes between the benchmark estimated model and various alternative policy regimes. Specifically, we introduce the parameter λ, which represents the percentage of additional consumption required for the representative household to be indifferent between the benchmark and the alternative policy regime. To compute this, the following household welfare equation, expressed in its log-linear form, must be

satisfied:

$$\mathrm{E}\left[W_t^{\mathrm{A}}\right] = \frac{1}{W_{ss}}\left[C_{ss}^{1-\sigma}\sum_{i=0}^{\infty}\beta^i(\widehat{C}_{t+i}+\lambda) - L_{ss}^{1+\eta}\sum_{i=0}^{\infty}\beta^i\widehat{L}_{t+i}\right] \tag{3.27}$$

After some algebra, the solution to the above equation is: $\lambda = \frac{(1-\beta)W_{ss}}{C_{ss}^{1-\sigma}}\left(\mathrm{E}\left[W_t^{\mathrm{A}}\right] - \mathrm{E}\left[W_t^{\mathrm{B}}\right]\right)$. A positive λ indicates that households need an additional percentage of their consumption as compensation in benchmark regime (**B**) to be indifferent to the alternative regime (**A**). Therefore, in the absence of compensation, the alternative regime would be preferred.

Regarding the government transfer mechanism for price smoothing, Figure 10 illustrates the impacts of two transfer policies on representative households, public finances, and the broader economy. If a transfer policy is implemented such that the amount transferred to households replicates the welfare path generated by an excise tax subsidy, households would theoretically be indifferent between the two policies. However, in practice, the economic outcome —particularly in terms of the output gap— would be more favorable under the transfer policy despite it leading to a worse outcome for the fiscal outlook characterized by higher financial cost, a larger deficit, and increased outstanding debt.

The improved economic outlook under the transfer policy can be attributed to several key factors. First, government transfers stimulate increased consumption of non-fuel goods, which partially boosts households' disposable income. However, the economic shock leads to a reduction in real wages, and the Central Bank's response of raising interest rates creates additional pressure on overall consumption. Also, households are incentivized to shift their spending toward non-fuel goods and prioritize savings. While the impact on real wages is less severe than in the full pass-through scenario —thanks to the fiscal impulse with transfers— the path of interest rates and inflationary pressures remain similar to those observed in the full pass-through case. Although the decrease in households' consumption of fuel goods may seem counterintuitive, it occurs because fuel prices are determined externally and remain unaffected by changes in household demand.

On the fiscal side, government expenses rise due to increased transfers, additional countercyclical investment, and higher financial costs associated with issuing new debt at elevated interest rates. Notably, the most significant expenditure increase stems from the financial costs incurred in a high-rate environment. This situation is further exacerbated by reduced tax revenues, primarily driven by lower non-fuel consumption, which diminishes overall tax intake. While there is some offset from higher payroll taxes due to increased labor hours, this gain is nearly canceled out by the effect of lower wages. As a result, the government faces a higher primary deficit and accumulates more debt compared to the scenario with the excise tax subsidy.

Suppose government transfers are increased to a level that ensures households do not experience a decline in welfare during the shock. In that case, the economic and fiscal outcomes mirror those in the initial transfer scenario but with amplified effects. The larger transfers further exacerbate the economic and fiscal disparities. This analysis suggests that while transfer programs can provide short-term benefits to households, they may lead to significant macroeconomic distortions. Moreover, government transfers may fail to stabilize both the economy and public finances simultaneously, highlighting the trade-offs involved in such policies.

To explore policies aimed at reducing fuel dependence as a strategy to mitigate fuel price shocks, we conducted a sensitivity analysis of the model's parameters related to fuel dependence, such as the share of fuel consumption, the price-elasticity of consumption's demand, and the fuel-input share in production. Figure 11 presents a comparison of household welfare in our benchmark economy against an economy with varying degrees of fuel dependence and price-elasticity. By analyzing 1,000 sample draws from the parameters' distribution and comparing its relative welfare to the benchmark model, we derived several key insights.

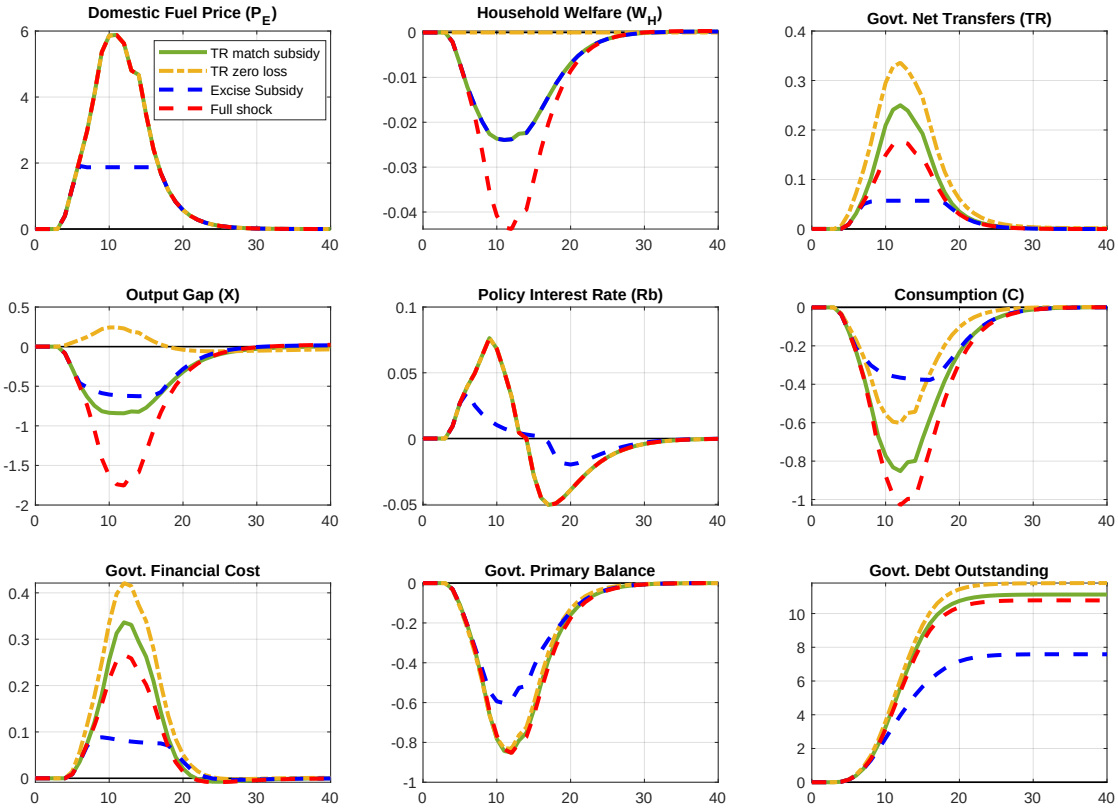
First, increasing the price-elasticity of consumption generally benefits households, as it allows for greater flexibility to adjust their consumption choices. However, this benefit is less pronounced compared to the significant gains per unit achieved by reducing the overall share of fuel consumption. The concave shape of the compensating variation scatter and the right-skewed distribution of the price-elasticity parameter is the reason for this result. Also, these findings suggest that policies aimed at reducing fuel dependence through direct replacements –such as increasing the availability of alternative energy sources or enhancing energy efficiency– could be more advantageous than those focusing solely on creating alternatives or close substitutes. Such an approach not only offers a more significant improvement in household welfare but is also a more robust solution to fuel price shocks.

Second, while reducing the fuel-input share in the production function does not significantly improve the household's welfare, it has a substantial impact on the economy and public finances. This impact is more important than the effect on household welfare. For example, decreasing the fuel-input share from the benchmark 8.5 percent to 4.0 percent significantly reduces the volatility of both the tax revenues and the public balance on average by 3 percentage points relative to the steady-state output.

Several factors contribute to the greater impact on public finances. Firstly, fuel dependence in the production function leads to a higher pass-through effect on general prices, particularly core inflation. As a result, monetary policy responds with sharper rate hikes, and non-fuel consumption declines more than in the benchmark scenario. With a larger drop in household consumption, key tax revenues, such as VAT, contract even more than in the benchmark. In summary, reducing fuel

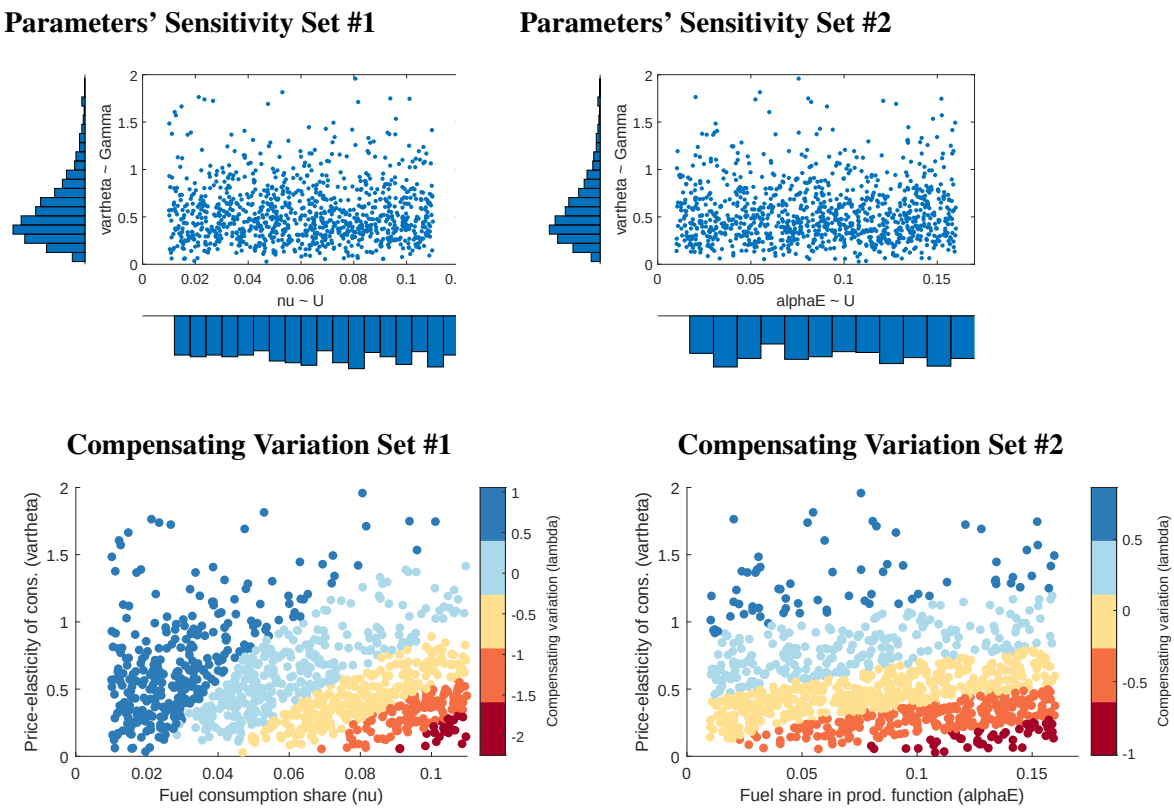
dependence in the production function eases the fiscal burden from interest rate hikes, improving the fiscal deficit and reducing public debt.

Figure 10. Impulse-Responses to the Govt. Transfers Policy Alternatives



Note: For each variable, the x-axis represents time in quarters, and the y-axis shows the deviation of the steady-state from the international fuel price shock from 2021q1 to 2023q4. The green lines show the combined price shock with government transfers matched to return the same welfare path of the excise tax policy; the orange lines show the combined price shock with a government transfers to guarantee a zero welfare loss of the households; the red dashed lines show the counterfactual model with the pure price shock without any policy intervention; the blue dashed lines is the Piecewise estimation output with the excise tax policy that puts a cap to the international fuel price shocks.

Figure 11. Sensitivity Analysis of Fuel Dependence Alternatives



Note: Figure shows the sensitivity of fuel parameters in the benchmark model using 1,000 draws of the distribution of fuel consumption share by households, $\nu \sim U(0.01, 0.11)$, fuel share in the production function, $\alpha_E \sim U(0.01, 0.16)$, and price-elasticity of consumption's demand, $\vartheta \sim \Gamma(14.55, 0.08)$. The compensating variation (λ) shows the percent of consumption the representative household needs to receive to be indifferent between the benchmark model ($\nu = 0.06,\ \alpha_E = 0.085,\ \vartheta = 0.56$) and an alternative economy with other parameters.

4 Conclusion

In this paper, we reviewed the history of Mexico's excise tax from 1980 to 2023, compiling public data on fuel prices, effective excise taxes, and fuel consumption. This comprehensive dataset allowed us to calculate the fiscal cost of tax relief and subsidies over this period, revealing that at its peak, these costs exceeded 3 percent of GDP. While Mexico has gradually reduced its dependence on fuel, the fiscal burden has lessened, yet the ongoing geopolitical risks that trigger international price shocks remain a significant threat to economic stability and fiscal health.

We then developed a standard New Keynesian DSGE model to evaluate the economic impacts of various excise tax regimes in managing energy price shocks. Our findings indicate that a flexible excise tax regime, coupled with fuel subsidies, can help the economy absorb shocks and mitigate adverse effects on other economic variables. This suggests that energy price-suppressing measures can effectively stabilize the economy in the face of temporary shocks. However, prolonged shocks pose a substantial fiscal challenge, highlighting the need for alternative strategies to reduce the fiscal burden and enable the economy to adjust more sustainably.

Policymakers must weigh the trade-offs between short-term economic stability and long-term fiscal health when designing fuel price stabilization measures. Although liberalizing domestic prices and eliminating subsidies may align prices with international markets, our historical analysis shows that sudden liberalization often leads to sharp price spikes with negative spillover effects. These spikes not only prove unpopular but also have significant economic repercussions. Therefore, a balanced approach that prioritizes both economic stability and fiscal sustainability is essential when addressing energy price shocks.

Future research should explore alternative measures and tax structures that help smooth price shocks while advancing environmental goals. It is crucial to design policy measures that balance economic stability with sustainable energy transitions. These alternative policies could include mechanisms that better align with long-term fiscal sustainability and environmental considerations, potentially involving gradual adjustments to excise taxes, targeted subsidies, and incentives for renewable energy adoption. By integrating these approaches, policymakers can create a more resilient economy capable of withstanding energy price volatility without compromising environmental objectives.

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Appendices

A Data Collection

For the analysis reported and estimation of the model, we use public data from the National Institute of Geography and Statistics (INEGI, for its Spanish acronym), the Central Bank of Mexico (Banxico), international fuel prices from Bloomberg, domestic fuel prices from the Mexican Ministry of Energy and the Energy Regulatory Commission (CRE, for its Spanish acronym), data of excise tax quotas published by the Mexican Ministry of Energy and in the Official Journal of Mexico (DOF, for its Spanish acronym), and non-public data on international and base prices from the Mexican Ministry of Finance.

- **Real GDP**: quarterly and seasonally adjusted GDP in pesos of 2018 from INEGI starting in the 1st quarter of 1993 to the 3th quarter of 2023.
- **Real Government Expenditure**: quarterly seasonally adjusted government consumption and public investment in pesos of 2018 from INEGI starting in the 1st quarter of 1993 to the 3th quarter of 2023.
- **Consumer Price Index**: monthly non-seasonally adjusted data for the aggregate CPI, core CPI, and energy subindex from INEGI starting in Jan-1990 to Dec-2023. These series were seasonally adjusted by applying the U.S. Census Bureau's X-13 ARIMA-SEATS program, using the logarithm of the series, and taking into account the holidays and other calendar effects. The data were transformed into quarterly series with simple averages.
- **Interest Rate**: monthly annual rate of Cetes-28 (Treasury Certificates) with 28-day maturity from Banxico starting in Jan-1990 to Dec-2023. The data were aggregated into quarterly series with simple averages and then transformed into annualized rates.
- **Domestic Fuel Prices**: monthly non-seasonally adjusted data on government-administered prices from the Mexican Ministry of Energy starting in Jan-1995 to Dec-2016. From January 2017, we use the monthly average market prices from the Regulatory Energy Commission (CRE, for its Spanish acronym). We put together these two pieces of information to complete a monthly series of domestic fuel prices for regular, premium, and diesel from Jan-1995 to Dec-2023. The prices were weight-averaged based on consumption levels for each type of fuel. The weights were updated every 5 years to capture changes in fuel demand. The data were transformed into quarterly series with simple averages.

- **International Fuel Prices**: as explained in the main text, international prices are an international reference converted to pesos and adjusted for transportation costs, margins, etc. From December 2018 to December 2023, we have access to non-public data on the international fuel prices used by the Ministry of Finance to decide the weekly adjustments to excise tax quotas for the three types of fuels consumed in Mexico. To extrapolate these prices backward, we used daily US Gulf Coast fuel prices from Bloomberg Terminal. The corresponding tickers are MOIGC87P Index for regular gasoline, MOIGC93P Index for premium gasoline, and DIEIGULP Index for diesel. The data in DIEIGULP Index only offers data from 2008, so we also extrapolate backward, taking advantage of its close correlation in levels with MOIGC87P Index. Prices were converted to pesos using daily exchange rates. We use a weighted average of the three fuel types. The weights are based on consumption levels, with a window of 5 years updates to capture changes in fuel demand. The data were transformed into quarterly series with simple averages.

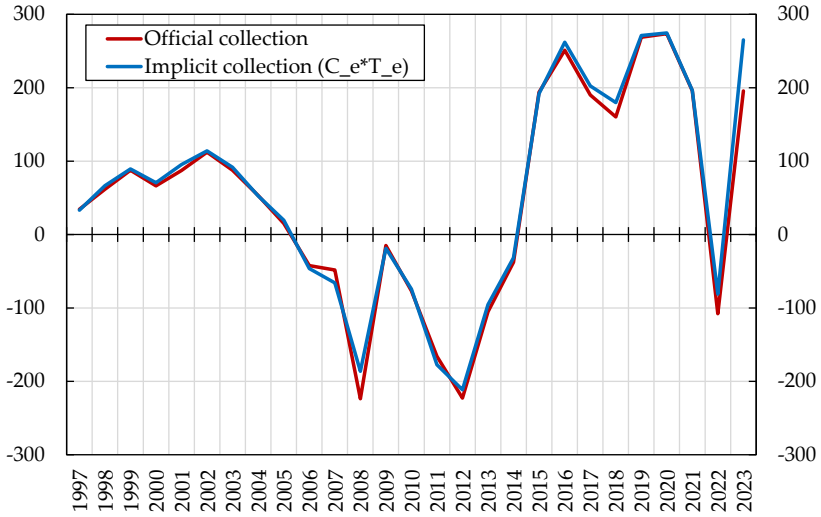
- **Base Prices**: daily non-public data from the Mexican Ministry of Finance for the three fuel types. The prices were weight-averaged based on consumption levels for each type of fuel. The weights were updated every 5 years to capture changes in fuel demand. The data were transformed into quarterly series with simple averages.

- **Excise Tax Quotas**: monthly non-seasonally adjusted data from the Ministry of Energy on the excise tax rate in pesos per liter from Jan-1995 to Dec-2016. From January 2017, we use weekly data collected from the DOF. We combine these two series of data into a monthly series of the excise fuel-tax quotas for regular, premium, and diesel from Jan-1995 to Dec-2023. The final figure is a weighted average based on consumption levels for each type of fuel. We update the weights every five years to capture changes in fuel demand. Finally, the data are transformed into quarterly series with simple averages. We can test the validity of this data by comparing the implied tax revenues derived from the effective excise tax rate and fuel demand figures with the Ministry of Finance's official accounts of excise tax receipts. Figure 12 presents the results of this exercise, which show that our data closely match the official collection figures.

All time series used in the model estimation were de-trended, namely the inflation rate, the interest rate, the real GDP, and the government expenditure. First, we filtered the data using an HP Filter with tail correction to reduce the end-of-sample bias problem. Usually, this algorithm has proven to be reliable for the Mexican data, see Banxico (2009). Then, we took the logarithm of the series and subtracted their mean values. For the estimation, we restrict the sample to be from the 4th quarter of 2000 to the 4th quarter of 2018.

Figure 12. Excise Tax on Fuels Collection

Billion pesos



Note: The graph shows the official figures for fuel excise tax collection and the collection implied by the effective excise tax quotas and fuel demand data.
Source: Data explained in the main text and Appendix A.

B Steady State and Log-Linearization

An important step in the model solution process is to find the steady-state or long-run solution of the model and log-linearize the system's equations.

Steady State Equations

$$A_{ss}=1;\ \ P_{\mathrm{N},ss}=1;\ \ \varepsilon_{\mathrm{E}_i,ss}=1;\ \ \varepsilon_{\mathrm{G},ss}=1;\ \ \varepsilon_{I_G,ss}=1;\ \ \varepsilon_{\mathrm{TR},ss}=1;\ \ \varepsilon_{\mathrm{M},ss}=1;\ \ \varepsilon_{\mathrm{A},ss}=1;$$

$$P_{\mathrm{E}_i,ss}=\varepsilon_{\mathrm{E}_i,ss};\ \ T_{\mathrm{E},ss}=\tau_{\mathrm{E}};\ \ P_{\mathrm{E},ss}=T_{\mathrm{E},ss}+P_{\mathrm{E}_i,ss};\ \ \overline{P}_{\mathrm{E},ss}=P_{\mathrm{E},ss};\ \ T_{ss}=1;$$

$$P_{ss}=\left[(1-\nu)P_{\mathrm{N},ss}^{1-\vartheta}+\nu P_{\mathrm{E},ss}^{1-\vartheta}\right]^{\frac{1}{1-\vartheta}};\ \ R_{ss}=P_{ss}\left(\frac{1}{\beta}-(1-\delta)\right);$$

$$MC_{ss}=\frac{\varphi-1}{\varphi}(1-\beta\theta)P_{\mathrm{N},ss};\ \ R_{\mathrm{B},ss}=R_{ss};\ \ B_{ss}=1;\ \ TR_{ss}=1;\ \ K_{\mathrm{G},ss}=\frac{1}{\delta};$$

$$W_{ss}=\left[A_{ss}K_{\mathrm{G},ss}MC_{ss}\left(\frac{\alpha_{\mathrm{K}}}{R_{ss}}\right)^{\alpha_{\mathrm{K}}}\left(\frac{\alpha_{\mathrm{E}}}{P_{\mathrm{E},ss}}\right)^{\alpha_{\mathrm{E}}}\right]^{\frac{1}{\alpha_{\mathrm{L}}}};$$

$$Y_{ss}=\left(\frac{R_{ss}}{R_{ss}-\delta\alpha_{\mathrm{K}}MC_{ss}}\right)^{\frac{\sigma}{\sigma+\eta}}\left[1+\frac{\tau_{\mathrm{C}}P_{\mathrm{N},ss}}{P_{ss}}(1-\nu)\left(\frac{P_{ss}}{P_{\mathrm{N},ss}+\tau_{\mathrm{C}}P_{\mathrm{N},ss}}\right)^{\vartheta}+\nu\frac{T_{\mathrm{E},ss}}{P_{ss}}\left(\frac{P_{ss}}{P_{\mathrm{E},ss}}\right)^{\vartheta}\right]\ldots$$

$$\ldots\left[\frac{1-\tau_{\mathrm{L}}}{P_{ss}}\left(\frac{1}{\alpha_{\mathrm{L}}MC_{ss}}\right)^{\eta}W_{ss}^{1+\eta}\right]^{\frac{1}{\sigma+\eta}};$$

$$C_{ss}=\left[\frac{(1-\tau_{\mathrm{L}})W_{ss}}{P_{ss}}\left(\frac{W_{ss}}{\alpha_{\mathrm{L}}MC_{ss}Y_{ss}}\right)^{\eta}\right]^{\frac{1}{\sigma}};$$

$$C_{\mathrm{N},ss}=(1-\nu)\left(\frac{P_{\mathrm{N},ss}}{P_{ss}}\right)^{-\vartheta}C_{ss};$$

$$C_{\mathrm{E},ss}=(\nu)\left(\frac{P_{\mathrm{E},ss}}{P_{ss}}\right)^{-\vartheta}C_{ss};$$

$$I_{ss}=\frac{\delta\alpha_{\mathrm{K}}MC_{ss}Y_{ss}}{R_{ss}};\ \ K_{ss}=\alpha_{\mathrm{K}}MC_{ss}\frac{Y_{ss}}{R_{ss}};\ \ L_{ss}=\alpha_{\mathrm{L}}MC_{ss}\frac{Y_{ss}}{W_{ss}};\ \ E_{ss}=\alpha_{\mathrm{E}}MC_{ss}\frac{Y_{ss}}{P_{\mathrm{E},ss}};$$

$$I_{\mathrm{G},ss}=Y_{ss}-C_{ss}-I_{ss};\ \ G_{ss}=I_{\mathrm{G},ss}+TR_{ss}+R_{\mathrm{B},ss}+B_{ss};$$

$$HW_{ss}=\left(\frac{1}{1-\beta}\right)\left(\frac{C_{ss}^{1-\sigma}-1}{1-\sigma}-\frac{L_{ss}^{1+\eta}}{1+\eta}\right);$$

$$\kappa=\frac{C_{ss}\left(\eta+\alpha_{\mathrm{L}}+1\right)+\alpha_{\mathrm{L}}\sigma Yss}{\alpha_{\mathrm{L}}C_{ss}};$$

$$Y_{f,ss}=Y_{ss};\ \ R_{f,ss}=R_{ss};\ \ X_{ss}=0;$$

Log-linearized Equations

$$\widehat{W}_t - \widehat{P}_t = \eta \widehat{L}_t + \sigma \widehat{C}_t; \quad \text{(1. Labor supply)}$$

$$\widehat{X}_t = \mathrm{E}_t \widehat{X}_{t+1} - \frac{\beta}{\sigma}\left(\frac{C_{ss}R_{ss}}{Y_{ss}P_{ss}}\right)\mathrm{E}_t\left(\widehat{R}_{t+1} - \widehat{\pi}_{t+1} - \widehat{R}_{f,t}\right); \quad \text{(2. IS equation)}$$

$$\widehat{C}_{\mathrm{N},t} = \widehat{C}_t + \vartheta(\widehat{P}_t - \widehat{P}_{\mathrm{N},t}); \quad \text{(3. Consumption of non-fuel)}$$

$$\widehat{C}_{\mathrm{E},t} = \widehat{C}_t + \vartheta(\widehat{P}_t - \widehat{P}_{\mathrm{E},t}); \quad \text{(4. Consumption of fuel)}$$

$$\widehat{Y}_t Y_{ss} = \widehat{C}_t C_{ss} + \widehat{I}_t I_{ss} + \widehat{I}_{\mathrm{G},t} I_{\mathrm{G},ss}; \quad \text{(5. Equilibrium condition)}$$

$$\begin{aligned} &P_{\mathrm{N},ss}C_{\mathrm{N},ss}(1+\tau_{\mathrm{C}})(\widehat{P}_{\mathrm{N},t} + \widehat{C}_{\mathrm{N},t}) + ... \\ &P_{\mathrm{E},ss}C_{\mathrm{E},ss}(\widehat{P}_{\mathrm{E},t} + \widehat{C}_{\mathrm{E},t}) + P_{ss}I_{ss}(\widehat{P}_t + \widehat{I}_t) + ... \\ &B_{ss}\widehat{B}_t - R_{\mathrm{B},ss}B_{ss}(\widehat{R}_{\mathrm{B},t-1} + \widehat{B}_{t-1}) = ... \\ &(1-\tau_{\mathrm{L}})W_{ss}L_{ss}(\widehat{W}_t + \widehat{L}_t) + ... \\ &R_{ss}K_{ss}(\widehat{R}_t + \widehat{K}_t) + TR_{ss}\widehat{TR}_t; \end{aligned} \quad \text{(6. Household budget constraint)}$$

$$\widehat{Y}_t = \widehat{A}_t + \alpha_{\mathrm{K}}\widehat{K}_t + \alpha_{\mathrm{L}}\widehat{L}_t + \alpha_{\mathrm{E}}\widehat{E}_t + \alpha_{\mathrm{G}}\widehat{K}_{\mathrm{G},t}; \quad \text{(7. Production function)}$$

$$\widehat{Y}_{f,t} = \frac{1}{\kappa}\frac{\eta+1}{\alpha_{\mathrm{L}}}(\widehat{A}_t + \alpha_{\mathrm{K}}\widehat{K}_t + \alpha_{\mathrm{E}}\widehat{E}_t + \alpha_{\mathrm{G}}\widehat{K}_{\mathrm{G},t}) + \frac{1}{\kappa}\frac{\sigma}{C_{ss}}(I_{ss}\widehat{I}_t + I_{\mathrm{G},ss}\widehat{I}_{\mathrm{G},t}); \quad \text{(8. Flexible-price output)}$$

$$\widehat{X}_t = \widehat{Y}_t - \widehat{Y}_{f,t}; \quad \text{(9. Output gap)}$$

$$\widehat{R}_{f,t} = \frac{\sigma}{\beta}\frac{P_{ss}}{C_{ss}R_{ss}}\mathrm{E}_t(I_{ss}\Delta\widehat{I}_{t+1} + I_{\mathrm{G},ss}\Delta\widehat{I}_{\mathrm{G},t+1}) - \frac{\sigma}{\beta}\frac{Y_{ss}P_{ss}}{C_{ss}R_{ss}}\mathrm{E}_t\Delta\widehat{Y}_{f,t+1} - \widehat{P}_t; \quad \text{(10. Neutral interest rate)}$$

$$\widehat{K}_{t+1} = (1-\delta)\widehat{K}_t + \delta\widehat{I}_t; \quad \text{(11. Law of motion for capital)}$$

$$\widehat{MC}_t = \alpha_{\mathrm{K}}\widehat{R}_t + \alpha_{\mathrm{L}}\widehat{W}_t + \alpha_{\mathrm{E}}\widehat{P}_{\mathrm{E},t} - \widehat{A}_t - \alpha_{\mathrm{G}}\widehat{K}_{\mathrm{G},t}; \quad \text{(12. Marginal cost)}$$

$$\widehat{K}_t = \widehat{MC}_t + \widehat{Y}_t - \widehat{R}_t; \quad \text{(13. Demand for capital)}$$

$$\widehat{L}_t = \widehat{MC}_t + \widehat{Y}_t - \widehat{W}_t; \quad \text{(14. Demand for labor)}$$

$$\widehat{E}_t = \widehat{MC}_t + \widehat{Y}_t - \widehat{P}_{\mathrm{E},t}; \quad \text{(15. Demand for fuel)}$$

$$\widehat{\pi}_{\mathrm{N},t} = \beta\mathrm{E}_t\widehat{\pi}_{\mathrm{N},t+1} + \kappa\frac{(1-\theta)(1-\beta\theta)}{\theta}\widehat{X}_t; \quad \text{(16. Phillips equation)}$$

$$\widehat{\pi}_{\mathrm{N},t} = P_{\mathrm{N},t} - P_{\mathrm{N},t-1}; \quad \text{(17. Core inflation)}$$

$$\widehat{P}_{\mathrm{E}_i,t} = \mu_{\mathrm{E}} + \rho_{\mathrm{E}}\widehat{P}_{\mathrm{E}_i,t-1} + \varepsilon_{\mathrm{E}_i,t}; \quad \text{(18. International fuel price)}$$

$$\overline{P}_{\mathrm{E},t} = P_{\mathrm{E},ss} + \widehat{\pi}_t; \quad \text{(19. Fuel price ceiling)}$$

$$\widehat{T}_{\mathrm{E},t} = \begin{cases} \tau_{\mathrm{E}} + \overline{P}_{\mathrm{E},t} - \widehat{P}_{\mathrm{E}_i,t}, & \text{if } \widehat{P}_{\mathrm{E}_i,t} > \overline{P}_{\mathrm{E},t} \\ \tau_{\mathrm{E}} & \text{if } \widehat{P}_{\mathrm{E}_i,t} \le \overline{P}_{\mathrm{E},t}. \end{cases}; \quad \text{(20. Excise tax on fuel)}$$

$$P_{\mathrm{E},t} = \widehat{T}_{\mathrm{E},t} + \widehat{P}_{\mathrm{E}_i,t}; \quad \text{(21. Domestic fuel price)}$$

$$\widehat{\pi}_t = (1-\nu)\widehat{\pi}_{\mathrm{N},t} + \nu\widehat{\pi}_{\mathrm{E},t}; \quad \text{(22. Headline inflation)}$$

$$\widehat{R}_{\mathrm{B},t} = \phi_{\mathrm{R}}\widehat{R}_{\mathrm{B},t-1} + (1-\phi_{\mathrm{R}})(\phi_\pi\widehat{\pi}_t + \phi_{\mathrm{X}}\widehat{X}_t) + \widehat{M}_t; \quad \text{(23. Monetary policy rule)}$$

$$\widehat{M}_t = \rho_{\mathrm{M}}\widehat{M}_{t-1} + \varepsilon_{\mathrm{M},t}; \quad \text{(24. Monetary policy shock)}$$

$$\widehat{P}_t = (1-\nu)\left(\frac{P_{\mathrm{N},ss}}{P_{ss}}\right)^{1-\vartheta}\widehat{P}_{\mathrm{N},t} + \nu\left(\frac{P_{\mathrm{E},ss}}{P_{ss}}\right)^{1-\vartheta}\widehat{P}_{\mathrm{E},t}; \quad \text{(25. General price level)}$$

$$\widehat{K}_{\mathrm{G},t} = (1-\delta)\widehat{K}_{\mathrm{G},t-1} + \delta\widehat{I}_{\mathrm{G},t}; \quad \text{(26. Govt. cap. law of motion)}$$

$$\widehat{G}_t = \widehat{I}_{\mathrm{G},t} + \widehat{TR}_t + \widehat{R}_{\mathrm{B},t-1} + \widehat{B}_{t-1} + \widehat{S}_{\mathrm{G},t}; \quad \text{(27. Govt. expenditure)}$$

$$\widehat{I}_{\mathrm{G},t} = \gamma_{I_G}\widehat{I}_{\mathrm{G},t-1} - (1-\gamma_{I_G})\phi_{I_G}(\widehat{B}_t - \widehat{Y}_{t-1} - \widehat{P}_{t-1}) + \widehat{S}_{I_G,t}; \quad \text{(28. Govt. investment)}$$

$$\widehat{\mathrm{TR}}_t = \gamma_{\mathrm{TR}}\widehat{\mathrm{TR}}_{t-1} - (1-\gamma_{\mathrm{TR}})\phi_{\mathrm{TR}}(\widehat{B}_t - \widehat{Y}_{t-1} - \widehat{P}_{t-1}) + \widehat{S}_{\mathrm{TR},t}; \quad \text{(29. Govt. net transfers)}$$

$$\widehat{T}_t = \tau_{\mathrm{C}}\left(\widehat{P}_{\mathrm{N},t} + (1-\nu)\widehat{C}_{\mathrm{N},t}\right) + \tau_{\mathrm{L}}\left(\widehat{W}_t + \widehat{L}_t\right) + \nu\left(\tau_{\mathrm{E}} + \widehat{P}_{\mathrm{E}_i,t} - \widehat{P}_{\mathrm{E},t}\right)\widehat{C}_{\mathrm{E},t}; \quad \text{(30. Govt. tax revenues)}$$

$$\widehat{S}_{\mathrm{G},t} = \rho_{\mathrm{G}}\widehat{S}_{\mathrm{G},t-1} + \varepsilon_{\mathrm{G},t}; \quad \text{(31. Govt. expenditure shock)}$$

$$\widehat{S}_{I_G,t} = \rho_{I_G}\widehat{S}_{I_G,t-1} + \varepsilon_{I_G,t}; \quad \text{(32. Govt. investment shock)}$$

$$\widehat{S}_{\mathrm{TR},t} = \rho_{\mathrm{TR}}\widehat{S}_{\mathrm{TR},t-1} + \varepsilon_{\mathrm{TR},t}; \quad \text{(33. Govt. net transfers shock)}$$

$$\widehat{A}_t = \rho_{\mathrm{A}}\widehat{A}_{t-1} + \varepsilon_{\mathrm{A},t}; \quad \text{(34. Productivity shock)}$$

$$\widehat{W}_{\mathrm{H},t} = \frac{1}{|W_{\mathrm{H},ss}|}\left(C_{ss}^{1-\sigma}\widehat{C}_t - L_{ss}^{1+\eta}\widehat{L}_t\right) + \beta \mathrm{E}_t\widehat{W}_{\mathrm{H},t+1}; \quad \text{(35. Household welfare)}$$

C Estimation

We do a Bayesian approach estimation of the parameters in Dynare using a maximum-likelihood function with Chris Sims' csminwel optimization algorithm[5]. We manually transform the non-linear version of the model into a log-linear model to estimate most of the parameters along with our prior means and distributions. The rest of the parameters were calibrated based on well-known assumptions in the literature, such as $\beta = 0.987$ (utility discount factor) consistent with a steady state nominal rate of 5.5 percent, Mexico's statistics of input's share in the production function ($\alpha_K = 0.5$, $\alpha_L = 0.27$, $\alpha_E = 0.09$, $\alpha_G = 0.08$,), an annual depreciation rate of 8 percent ($\delta = 0.08$), and the household's share of fuel expenditures in the CPI statistics ($\nu = 0.06$). For the fiscal parameters, we use the equivalent tax rates applied in the tax code such that the VAT is $\tau_{\mathrm{C}} = 16\%$, the personal income tax (PIT) on wages is $\tau_{\mathrm{L}} = 35\%$, and the excise tax rate of $\tau_{\mathrm{E}} = 5.5$ pesos per liter. The estimated parameters with their priors are shown in Table 4. Also, one can see

[5] See Adjemian, Bastani, Juillard, Karamé, Mihoubi, Mutschler, Pfeifer, Ratto, Rion, and Villemot (2022) and its web page documentation at www.dynare.org.

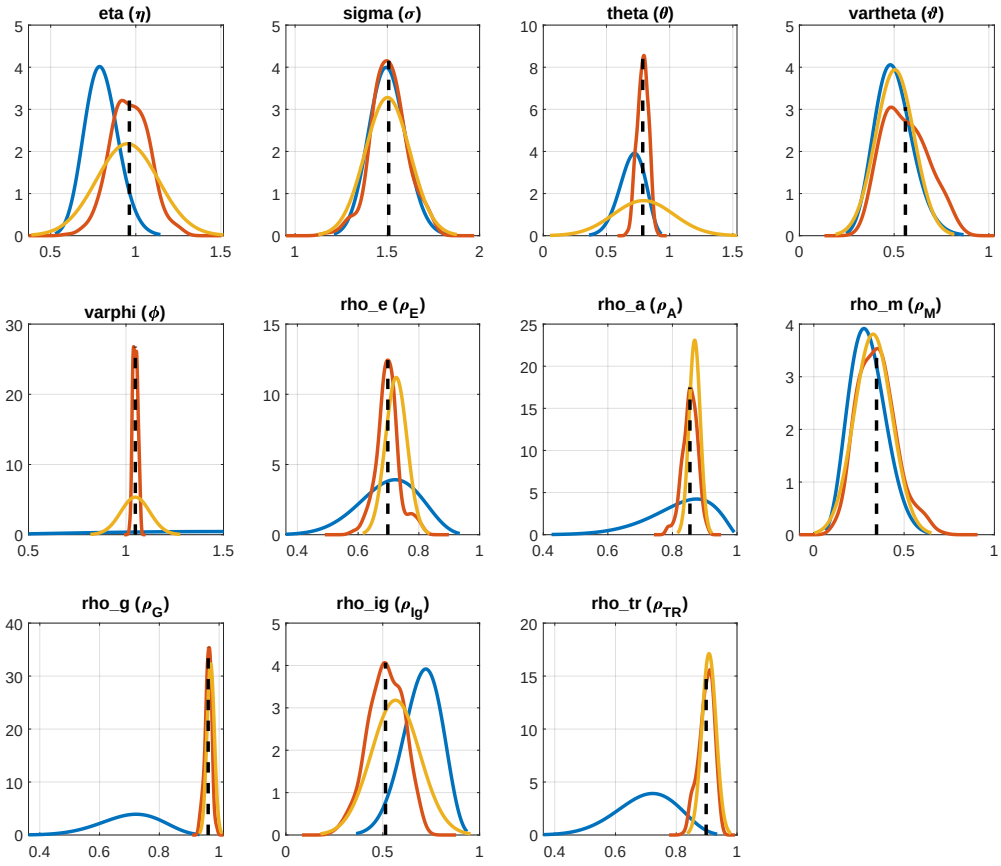
the comparison between prior distributions and posterior distributions results from the Metropolis-Hastings algorithm on Figure 13 and Figure 14.

Table 4. Prior Distributions and Parameter Estimation Results

Parameters	Prior Mean	Post. Mean	90% HPD interval		Prior Dist.	Post. Std.Dev
η	0.800	0.962	0.782	1.136	Gamma	0.100
σ	1.500	1.507	1.378	1.703	Gamma	0.100
θ	0.700	0.787	0.720	0.855	Beta	0.100
ϑ	0.500	0.559	0.379	0.751	Gamma	0.100
φ	2.000	1.048	1.030	1.068	Gamma	1.000
ρ_E	0.700	0.698	0.617	0.748	Beta	0.100
ρ_A	0.820	0.854	0.820	0.889	Beta	0.100
ρ_M	0.300	0.347	0.182	0.507	Beta	0.100
ρ_G	0.700	0.963	0.944	0.979	Beta	0.100
ρ_{I_G}	0.700	0.514	0.392	0.676	Beta	0.100
ρ_{TR}	0.700	0.898	0.860	0.942	Beta	0.100
γ_{I_G}	0.700	0.673	0.522	0.791	Gamma	0.100
γ_{TR}	0.700	0.457	0.360	0.591	Gamma	0.100
ϕ_{I_G}	0.500	0.533	0.395	0.648	Gamma	0.100
ϕ_{TR}	0.500	0.636	0.440	0.856	Gamma	0.100
ϕ_R	0.700	0.742	0.605	0.897	Beta	0.100
ϕ_π	1.500	1.504	1.333	1.628	Gamma	0.100
ϕ_X	0.125	0.104	0.001	0.189	Gamma	0.100
μ_E	2.110	1.531	1.260	1.855	Gamma	0.200
σ_A	1.000	0.160	0.128	0.180	Inv.Gamma	Inf
σ_{E_i}	1.000	0.372	0.328	0.418	Inv.Gamma	Inf
σ_M	1.000	0.172	0.140	0.204	Inv.Gamma	Inf
σ_G	1.000	0.171	0.140	0.198	Inv.Gamma	Inf
σ_{I_G}	1.000	0.115	0.100	0.130	Inv.Gamma	Inf
σ_{TR}	1.000	0.149	0.123	0.173	Inv.Gamma	Inf

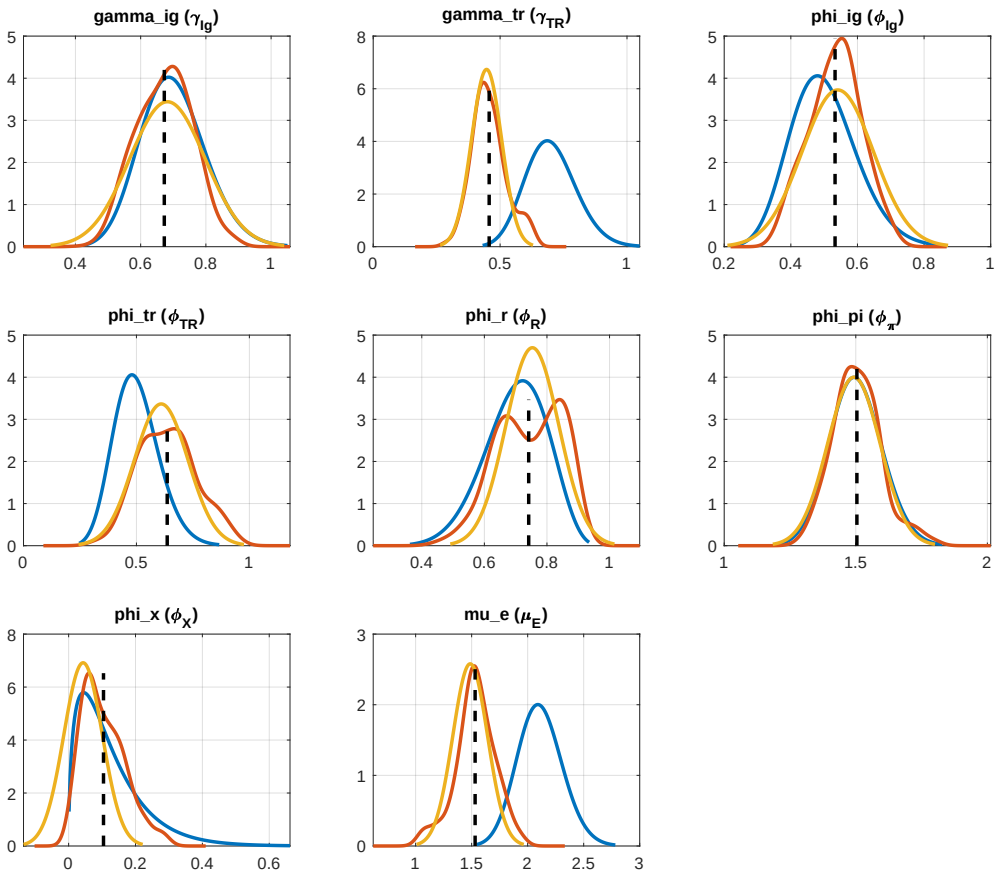
Note: 90% HPD interval refers to the Highest Probability Density with $100(1-\alpha)\%$.

Figure 13. Prior vs. Posterior Distributions



Note: Distributions for Priors, Posteriors, Posteriors using Laplace approximation at posterior modes, and posterior means in black dashed lines.

Figure 14. Prior vs. Posterior Distributions



Note: Distributions for Priors, Posteriors, Posteriors using Laplace approximation at posterior modes, and posterior means in black dashed lines.