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Renta petrolera y valorización fiscal en México (1990–2023): evidencia estructural mediante VECM

Oil rent and fiscal valorization in Mexico (1990–2023): structural evidence using VECM

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Abstract

This study analyzes the structural link between the energy sector and public finances in Mexico by employing a vector error correction model (VECM) with robust inference and an incorporated regime shift. The analysis focuses on the joint long- and short-term dynamics between federal government oil-related budget revenues and a set of fundamental energy valorization variables: total crude oil production, oil exports measured in Mexican pesos, and domestic sales of petroleum products. The study is situated within the context of an energy transition characterized by a sustained decline in crude oil production—reaching its sharpest contraction in 2016—an international price collapse—also bottoming out that same year—and a gradual institutional reconfiguration following the 2014 energy reform. These processes converge in 2016 as a critical turning point, justifying the inclusion of a structural break variable from that moment onward. The model identifies a stable cointegration relationship between public revenues and the resource valorization channels—exports and domestic consumption—while production operates as an exogenous variable, with no significant fiscal effect. The results reveal a pattern of fiscal dominance: public revenues adjust to imbalances, but not the energy determinants, reflecting an institutional framework in which fiscal policy responds to oil sector dynamics without structurally influencing them. Taken together, the findings provide an empirical assessment of the fragility of Mexico's fiscal-energy nexus and underscore the need for countercyclical rules and robust institutional mechanisms in the face of high volatility and structural transformation.

Keywords: Oil rent, Fiscal valorization, Cointegration, VECM model, Energy reform, Mexico.
JEL Classification: E62, Q43, C32.

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Resumen

Este estudio analiza el vínculo estructural entre el sector energético y las finanzas públicas en México, mediante un modelo vectorial de corrección de errores (VECM) con inferencia robusta y ruptura de régimen incorporada. El análisis se centra en la dinámica conjunta de largo y corto plazo entre los ingresos presupuestarios del gobierno federal por concepto petrolero y un conjunto de variables fundamentales de valorización energética: la producción total de crudo, las exportaciones petroleras en pesos mexicanos y las ventas internas de productos petrolíferos. El estudio se sitúa en un contexto de transición energética marcado por la caída sostenida en la producción de crudo —con su contracción más pronunciada en 2016—, colapso internacional de precios —también en su punto mínimo ese año— y reconfiguración institucional gradual tras la reforma energética de 2014. Estos procesos convergen en 2016 como momento crítico de inflexión, lo que justifica la incorporación de una variable estructural a partir de ese punto. El modelo identifica una relación de cointegración estable entre los ingresos públicos y los canales de valorización del recurso —exportaciones y consumo interno—, mientras que la producción opera como variable exógena, sin efecto recaudatorio significativo. Los resultados revelan un patrón de dominancia fiscal: el ingreso público se ajusta ante desequilibrios, pero no los determinantes energéticos, reflejando un marco institucional en el que la política fiscal responde al entorno petrolero sin incidir estructuralmente sobre él. En conjunto, los hallazgos ofrecen una lectura empírica de la fragilidad del canal fiscal-energético mexicano, y subrayan la necesidad de reglas contracíclicas y mecanismos institucionales sólidos frente a escenarios de alta volatilidad y transformación estructural.

Palabras clave: Renta petrolera, Valorización fiscal, Cointegración, Modelo VECM, Reforma energética, México.
Clasificación JEL: E62, Q43, C32.

1. Introduction

The link between the energy sector and public finances has been one of the most relevant structural features of the Mexican economy in recent decades. In particular, budget revenues derived from oil-related activities have constituted an important source of public spending financing, even in contexts of energy transition, production decline, or institutional reforms. Throughout its recent history, Mexico has financed a significant portion of its expenditures through crude oil rent, which between 2000 and 2010 accounted for 30% to 40% of federal government revenues (Campodónico, 2008; Ros, 2011). This dependence generated high fiscal vulnerability, reflected in procyclical spending and exposure to adverse terms-of-trade shocks (Reyes-Loya and Blanco, 2008; Tordo, 2011; Raouf, 2021)[1].

This pattern changed significantly following the 2014 energy reform, which reconfigured the sector's commercial and tax regimes. The structural decline in crude oil production, the increase in gasoline and diesel imports, and the liberalization of domestic prices altered fiscal flows, shifting the weight of public revenues from exports toward domestic consumption of petroleum products (Sánchez, 2016). Added to this was the intensive use of the Special Tax on Production and Services (IEPS, its acronym in Spanish) as a stabilization instrument, which introduced high sensitivity of tax collection to exchange rate factors and discretionary fiscal decisions (Valencia *et al.*, 2025). As a result, oil revenues became more volatile and their predictability eroded (Pascual *et al.*, 2018).

In this new environment, understanding the internal mechanisms through which energy production is converted into fiscal revenue becomes essential. While the literature has documented cointegration relationships between international crude prices and macroeconomic variables such as exchange rates or stock returns (Domínguez-Gijón *et al.*, 2018; Basher *et al.*, 2016), the structural link between fiscal revenues, production volumes, and commercialization channels has not been explicitly modeled. This omission limits our understanding of the real and nominal interactions of public revenue (Volkov and Yuhn, 2016), especially in a context where Mexico has shifted from being a net exporter to a net importer of petroleum products.

From an accounting perspective, oil produced by Pemex can either be exported or directed to the domestic market. In both cases, fiscal revenues do not depend exclusively on the volume extracted, but on how that flow is valorized and taxed. Operational decisions, relative prices, tax design, and the institutional regime determine the extent to which extraction translates into public rent. This distinction is key in a context of energy transition, declining reserves, and growing uncertainty about Pemex's structural role in public finances.

This paper addresses this gap through the estimation of a vector error correction model (VECM), which allows for the analysis of both long- and short-term joint dynamics between federal government oil-related budget revenues and a set of fundamental energy valorization variables: total crude oil production, oil exports in Mexican pesos, and domestic sales of petroleum products. These three dimensions represent, respectively, the physical source, external flows,

[1] Villafuerte and López-Murphy (2010) document that in oil-dependent countries –including Mexico– fiscal policy has exhibited a markedly procyclical pattern: during the boom of 2003–2008, public spending expanded at a faster pace than revenues, which increased non-oil primary deficits, while in the 2009 price collapse an abrupt adjustment was undertaken. The authors show that even moderate declines in the price of crude oil (for example, 10 dollars per barrel) generate considerable financing needs and significantly deteriorate the fiscal position of these countries. Consequently, they warn that the absence of adequate countercyclical mechanisms accentuates the structural vulnerability of public finances to the volatility of international oil prices.

and the fiscal valorization process, understood as the transformation of the oil base into public revenue, both through exports and the domestic commercialization of petroleum products. Unlike studies that directly introduce the crude oil price, this model internalizes it through variables that incorporate the combined effects of international prices, exchange rates, and domestic market conditions.

The estimation is conducted with robust inference using moving block bootstrap (MBB), in response to the statistical properties of energy series, which are characterized by conditional heteroskedasticity, autocorrelation, and multiple structural breaks (Bedin *et al.*, 2021; Abdelkawy and Al Shammre, 2024; Śmiech *et al.*, 2021). In addition, a structural regime shift variable is incorporated starting in 2016, representing the effective implementation of the energy reform and the turning point in international oil prices.

The main findings show that federal oil rent is structurally linked to the resource valorization channels –exports and domestic sales– while crude oil production operates as a variable with no significant fiscal capacity. This configuration reveals a dynamic of fiscal dominance: in the face of imbalances, it is public revenue that adjusts, not the sector's operational variables. The observed pattern is consistent with an institutional regime in which fiscal policy reacts to energy sector conditions but does not drive them.

Furthermore, a structural break is identified starting in 2016, coincident with the lowest point in the international price cycle and the operational consolidation of the energy reform initiated in 2014. The inclusion of a structural dummy captures this regime shift parsimoniously, reflecting a profound reconfiguration of the link between oil rent and public revenue. Taken together, the results provide empirical evidence of the institutional fragility of Mexico's fiscal-energy channel and its implications for fiscal sustainability in an environment of high volatility and productive transition.

In this article, oil rent is operationally understood as the federal government's budgetary revenues derived from oil activity. This definition emphasizes the fiscal dimension, that is, the resources effectively captured by the public treasury from crude oil exploitation, whether through exports or domestic sales of petroleum products. Under this conception, rent is not identified with the physical production of hydrocarbons, but rather with the valorization flows that transform that material base into public revenue, within an institutional framework in which tax design and relative prices play a decisive role.

This approach differs from the "traditional" calculation of oil rent, defined by international organizations such as the International Monetary Fund [IMF] (2012) as revenues exceeding all production costs plus a normal return on capital. While the classical notion corresponds to the theoretical economic surplus that can be taxed, the approach adopted here focuses on the rent effectively captured by the State in Mexico. The distinction is particularly relevant in an institutional context where Pemex operates as a conglomerate of subsidiaries with separate accounting (SHCP, 2019) and where the tax burden fell primarily on the exploration and production subsidiary through the Shared Utility Duty (Pemex, 2025). Under these conditions, the magnitude of fiscal rent depends not only on international prices or extraction costs, but also on the allocation of revenues among subsidiaries and on the commercialization channels –exports or domestic consumption– through which production is converted into public income.

The paper is organized into five sections. Following this introduction, Section 2 reviews the relevant literature. Section 3 analyzes the institutional context and structural changes in the fiscal-energy link. Section 4 presents the empirical methodology and model design. Section 5 discusses the main results and their interpretation.

2. Literature Review

The relationship between the energy sector and public revenues has been widely studied in oil-dependent economies such as Mexico. However, the Mexican context is characterized by a structural transformation that has redefined the dynamics of this link. Since 2014, Mexico has shifted from being a net exporter of hydrocarbons to a net importer of petroleum products, a change that has altered the way in which the energy sector contributes to public finances. This transition has been driven by a combination of structural factors, including reduced productive capacity of Petróleos Mexicanos (Pemex), increasing reliance on refined products, and government-regulated domestic pricing policies.

Crude oil production capacity in Mexico, which has historically been a key source of public revenues, has experienced an evolution marked by structural and policy constraints that limit its responsiveness to market signals. Truett and Truett (1998) highlight that crude oil production in Mexico does not respond significantly to variations in international oil prices. Their findings, based on a translog cost model for the Mexican oil industry, reveal negative and inelastic input demand elasticities for crude oil and natural gas extraction, indicating that production decisions are more influenced by operational constraints, long-term investment policies, and Pemex's installed capacity. This is consistent with the fact that even during periods of high prices, crude oil production in Mexico has shown a declining trend, demonstrating that international oil prices are not a direct determinant of supply.

A relevant contribution to the discussion comes from Martínez and Herrera (2006), who define oil rent as the difference between the market value of extracted crude oil and operating costs, including exploration, development, and extraction. Their analysis shows that between 1985 and 2005, the magnitude of this rent was determined primarily by the evolution of the international price of the Mexican export blend and, to a lesser extent, by production volumes and

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unit costs. Martinez and Herrera emphasize that, in a context where Pemex operated as a state monopoly in exploration and production, the highly volatile nature of prices was directly transmitted to fiscal revenues, deepening public finance dependence on this source. This approach illustrates how the measurement of oil rent in Mexico cannot be separated from the fiscal regime applied to Pemex and from its role as a budgetary pillar.

In this regard, the inelasticity of production is exacerbated by subsidy policies and domestic price regulations, which also affect the consumption of refined products. Ortega and Medlock (2021) show that fuel consumption in Mexico is inelastic, meaning it does not respond significantly to variations in international prices. This is because the government regulates domestic prices through the Special Tax on Production and Services (IEPS), which acts as a subsidy mechanism. During periods of high international prices, the government absorbs part of the cost by reducing the IEPS, while in periods of low prices, it increases this tax to capture additional revenues. This policy decouples domestic consumption from international oil prices, making demand and consumption dynamics more dependent on fiscal policies than on global market conditions.

Moreover, energy reforms and Pemex's corporate restructuring have transformed Mexico's sources of oil-derived revenues. Martínez and Herrera (2021) show that the energy reforms not only altered Pemex's organizational structure but also reduced its refining capacity and increased imports of petroleum products. This weakened state control over oil rents and shifted the focus of public revenue from crude oil exports to domestic consumption of refined products. The loss of production capacity and the need to import petroleum products reconfigured the flow of revenues derived from the energy sector, reducing dependence on international oil prices.

Valencia *et al.* (2025) complement this view by showing that oil shocks have asymmetric effects on public finances depending on their nature. While demand shocks generate positive fiscal adjustments, supply shocks that limit global production tend to have negative effects in countries like Mexico. However, since Mexico has transitioned from being a net exporter to a net importer of petroleum products, these effects are even more complex. Subsidy policies and domestic price regulations buffer the impact of international prices on domestic consumption, weakening the link between oil price fluctuations and fiscal revenues.

This issue is not exclusive to the Mexican case. Baunsgaard *et al.* (2003), in their analysis of the fiscal policy in Nigeria –another economy highly dependent on oil revenues– found that volatility in crude oil prices has induced procyclical fiscal behavior, weakening the state's ability to maintain a stable public spending path. Based on this diagnosis, the authors propose a framework based on the permanent income principle, whereby the government should save a significant portion of oil revenues during boom periods and finance its current expenditures from the returns on these savings, rather than relying directly on the extraction of exhaustible resources. Implementing this approach requires the design of explicit fiscal rules, particularly concerning the non-oil primary deficit, as a tool to decouple the public budget from international oil price cycles.

Nonetheless, Baunsgaard *et al.* (2003) warned that such rules can only be effective if supported by a robust institutional architecture. In the Nigerian case, as in Mexico, challenges arise from fiscal federalism, low budget execution quality, and limited credibility of stabilization funds. In this context, the author emphasizes the need to accompany fiscal rules with complementary structural reforms, including more transparent intergovernmental allocation mechanisms, greater accountability in the use of oil rents, and substantial improvements in expenditure planning.

Faced with this reality, Esquivel and Peralta (2013) propose a transition from a fiscal approach based on observed revenues toward one centered on the concept of structural balance. This proposal seeks to isolate the transitory effects stemming from international crude oil prices and business cycle volatility, advocating instead for a fiscal rule based on an annual structural surplus equivalent to 0.5% of GDP.

The central argument posed by Esquivel and Peralta (2013) is based on the recognition that Mexico's dual status –as a crude oil exporter and refined product importer (such as gasoline)– generates contradictory fiscal effects. On the one hand, export revenues benefit from high prices; on the other, those same high prices increase the cost of gasoline imports, which, under the IEPS-based subsidy scheme, may even turn revenues into net fiscal subsidies.

In this sense, the stability of domestic revenues, and particularly the behavior of Pemex's domestic sales, becomes central to the sustainability of public finances. Empirical evidence shows that, in the face of a shrinking export platform and growing domestic consumption of refined products, these revenues have assumed increasing importance as a fiscal source.

Finally, Sanchez (2016) highlights how, despite exporting approximately 9 billion barrels of crude oil between 2000 and 2014, Mexico's oil stabilization fund had accumulated only 2.9 billion dollars by 2014. This paradox of abundance reflects inefficient management of oil revenues, where petroleum-derived resources were used to finance current expenditures rather than being accumulated in a sovereign wealth fund that could mitigate revenue fluctuations. This underscores the absence of a solid institutional framework to manage oil rents, reinforcing the need for a stability-oriented fiscal approach and a comprehensive vision of the energy sector.

Despite the extensive literature on the relationship between the energy sector and public revenues in Mexico, much of the research has focused on the effects of international crude prices, leaving relatively unexplored the role of internal sector dynamics as structural determinants of tax collection. This study contributes empirical evidence on how federal government oil revenues are structurally linked to fundamental components of the national energy system. Through a cointegration and error correction approach, long-term relationships and short-term adjustment mechanisms are identified between oil public revenues, crude oil production, oil exports, and domestic sales of petroleum products. This perspective allows for a more precise understanding of the channels through which the fiscal valorization of oil rent in Mexico is configured. The analysis is framed within an institutional transformation process that began with the 2014 energy reform, whose effects –although legally established since that year– did not immediately materialize in fiscal flows due to the nature of operational implementation, the staggered entry of new contracts, and the persistence of inherited fiscal schemes. Furthermore, between 2014 and 2016, the sector faced intense external pressure: oil prices experienced a prolonged decline, reaching their lowest point in 2016, alongside a significant contraction in proven reserves. For these reasons, the year 2016 constitutes the focal point for identifying the structural shift in the fiscal-energy link, combining a new institutional framework with a profound reconfiguration of the sector's economic conditions.

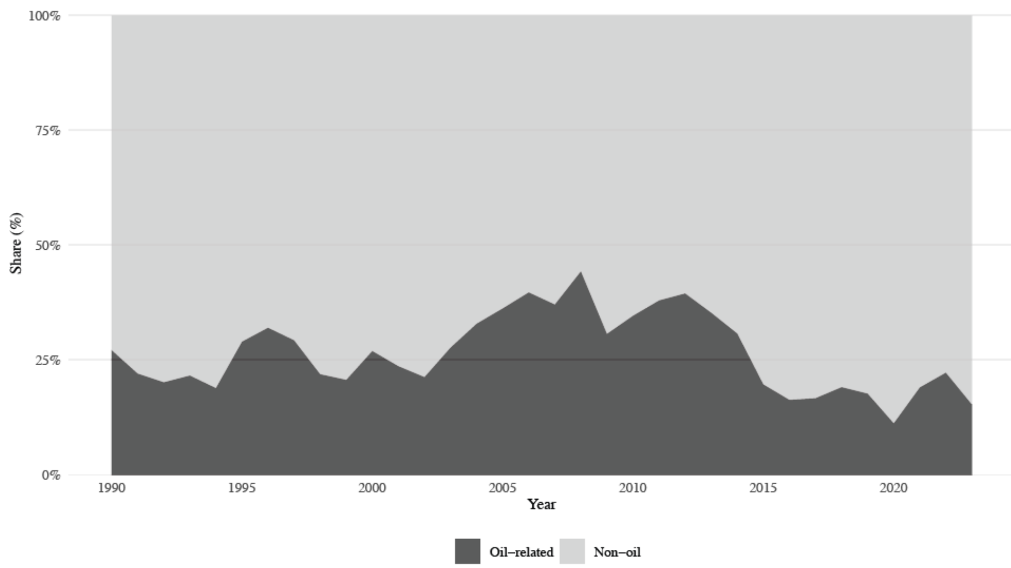
3. Structural Transformations of the Fiscal-Energy Link in Mexico

In recent decades, the link between the energy sector and public finances in Mexico has undergone a profound structural transformation. What was once a direct and dominant dependence of federal budget revenues on oil income has evolved into a more fragmented, vulnerable, and fiscally complex system. As illustrated in Figure 1, oil revenues represented a significant share of total federal budget revenues over the past decades. Between 1990 and 2002, their share hovered around 25%. Subsequently, during the period 2003–2014, this proportion rose steadily, reaching between 30% and 40%. Starting in 2015, following the implementation of the energy reform and changes in the sector's external dynamics, oil revenues began to decline markedly, falling below 15% of the federal budget by 2022 (Banco de México, 2024). This behavior reflects a significant reordering of the country's fiscal architecture.

This decline should not be interpreted merely as a loss of relevance of the energy sector, but rather as a reconfiguration of its monetization channels and associated tax design. Whereas oil rent was historically captured primarily through crude oil exports, in the current context its fiscal role has increasingly been mediated by domestic consumption of petroleum products and indirect mechanisms such as the IEPS. At the same time, the decreasing relative weight of these revenues has coincided with greater reliance on non-energy tax sources, which has increased the budget's exposure to external volatility and the structural fragility of the tax system[2].

[2] Segal (2011) shows that, beginning in the mid-2000s, the Mexican fiscal framework started to shift toward mechanisms linked to domestic consumption of petroleum products, particularly through the IEPS. Between 2006 and 2008, this tax effectively operated as a subsidy, with a cost of up to 1.8% of GDP in 2008, while also exhibiting regressive incidence by concentrating its benefits on higher-income households. These results illustrate how the transformation of oil-related taxation implied not only a relative reduction in revenues but also an institutional reconfiguration that revealed the structural fragility of the tax system.

Figure 1. *Annual share of oil and non-oil revenues in total federal budget*



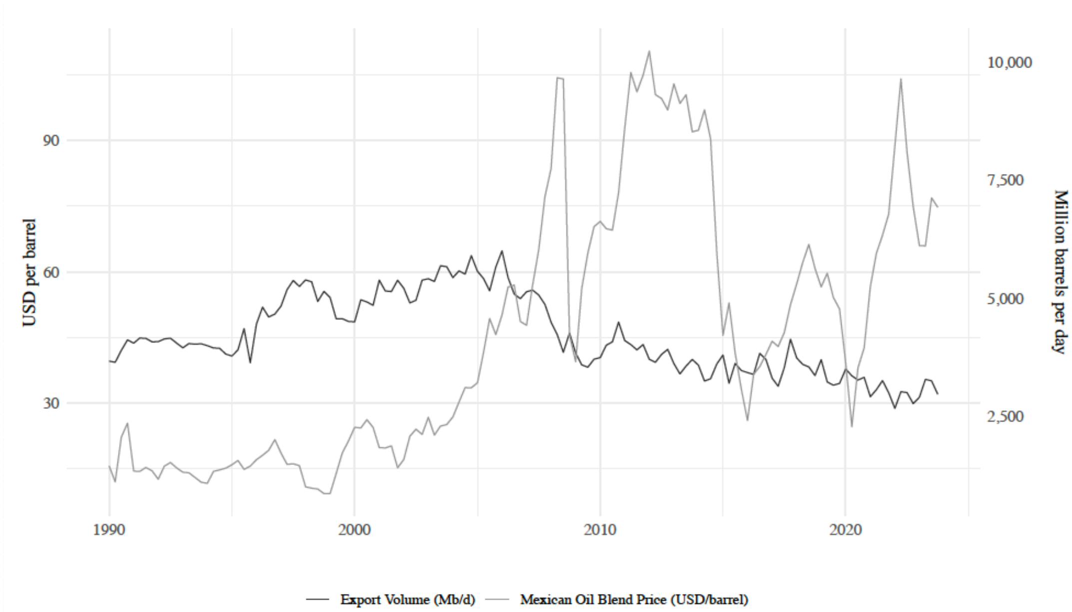
Source: Own elaboration based on Banco de México (2024) data.

Figure 2 delves into the nature of this structural reconfiguration by showing the joint evolution of crude oil export volumes (right axis) and the price of the Mexican oil mix (left axis). While the price has exhibited a volatile dynamic –reaching peaks of around USD 104 per barrel in 2008, 2012, and again in 2022– export volumes fell from more than 3.3 million barrels per day in 2004 to less than 1 million in 2022. This divergence indicates that export revenues ceased to be determined exclusively by international price cycles: even during periods of high quotations, the smaller export platform limited the State's capacity to capitalize on those favorable phases.

In particular, it is noteworthy that increases in oil prices have not translated into proportional increases in export volumes, suggesting either a structural loss in export platform capacity or a growing reallocation of crude oil toward the domestic market. This decoupling between prices and quantities reflects a new configuration of the fiscal-energy link, in which oil rent can no longer be understood simply as a function of the international price, but rather as the outcome of a combination of operational constraints, commercial decisions, and institutional conditions that shape the external monetization channel of the resource[3].

[3] Using monthly data from 1990–2005, Reyes-Loya and Blanco (2008) demonstrated that revenues derived from oil exports behaved inversely to non-oil tax collection, such that upswings in external rents reduced the incentives to strengthen the domestic tax base. This finding helps explain why the sustained decline in export volumes since the mid-2000s entailed not only a quantitative adjustment but also a structural challenge for fiscal revenue.

Figure 2. *Joint evolution of crude oil export volume (million barrels per day) and the Mexican oil blend price (USD per barrel).*



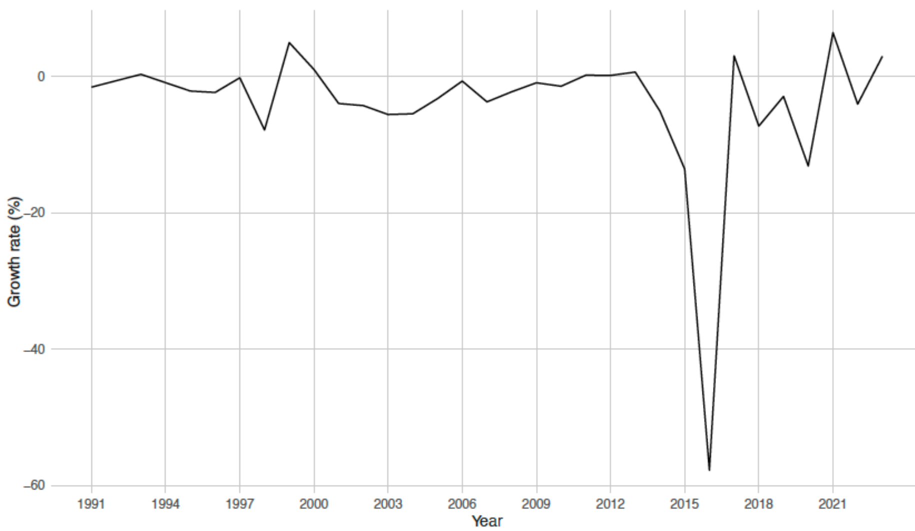
Source: Own elaboration based on Pemex (2024) data.

This disconnection between international prices and export volumes is not solely the result of commercial decisions; rather, it reflects a structural deterioration in the productive capacity of the energy sector. As domestic production has declined, the system has increasingly relied on imports to meet domestic demand, which limits the export platform and reconfigures the fiscal-energy link. In this context, the evolution of proven crude oil reserves is key to understanding the operational constraints underlying this transformation. Figure 3 presents the annual variation in total proven crude oil reserves in Mexico between 1991 and 2023. During the 1990s and 2000s, fluctuations remained contained, reflecting a certain continuity in reserve replenishment relative to extraction volumes. This sustained behavior suggests a still-functional energy platform capable of supporting the model based on crude oil exploitation as a strategic fiscal and commercial source.

However, starting in 2014, a clear transition toward a different pattern is observed. After two years of moderate declines, 2016 recorded an abrupt 58% contraction, the largest in the entire period considered. This drop represents a turning point: unlike previous episodes, it was not followed by a clear or sustained recovery. On the contrary, the subsequent period is characterized by a sequence of erratic variations, predominantly negative or close to zero. Operationally, this behavior indicates an environment in which reserve replenishment has become more uncertain and limited, progressively reducing the national energy system's margin of maneuver[4].

The subsequent instability in reserve evolution –with years of slight rebounds followed by new declines– suggests a stage characterized by reduced exploration capacity, lower replenishment rates, and greater technical or financial difficulties in maintaining previous reserve levels. Taken together, this dynamic reinforces the idea that the transformation of the fiscal-energy link is not solely the result of political decisions (such as the 2014 reform), but also of profound material constraints that affect the viability of the traditional export-oriented model.

Figure 3. *Annual growth rate of proven crude oil reserves in Mexico (proven, probable, and possible; period 1991–2023).*



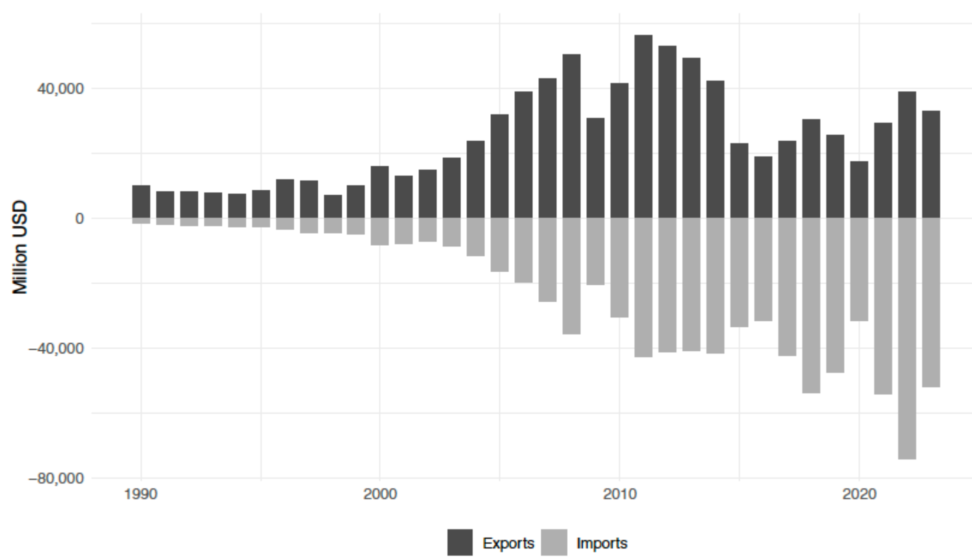
Source: Own elaboration based on data by the Secretaría de Energía (2024).

Figure 4 provides further evidence of the structural change in the role of the energy sector within public finances by showing the evolution of Mexico's oil exports and imports between 1990 and 2023. During the early years of the period analyzed, the country consistently recorded sizable trade surpluses: in 1996, for example, exports reached 11,817 million USD compared to 3,072 million in imports. The trade balance expanded strongly during years of high international

[4] Romo (2015) documents that the Cantarell mega-field reached a peak production level of 2.2 million barrels per day in 2003, but by 2014 its contribution had declined to 351 thousand barrels per day. In parallel, proven reserves fell from 9,000 to 2,200 million barrels between 2002 and 2013, while the annual decline rate accelerated to 20.3% during 2006-2011, well above that observed in other giant fields. These results confirm that the transformation of the fiscal-energy nexus cannot be understood solely in terms of political decisions, but also as a consequence of the structural depletion of the material reserve base.

prices: in 2008, the surplus exceeded 14,978 million USD, with exports totaling 50,635 million and imports 35,657 million. However, this pattern was reversed at the beginning of 2014; in that year, exports (42,369 million) only slightly exceeded imports (41,490 million), inaugurating a period of persistent structural deficits. In the more recent stage, these gaps have widened: in 2022, the deficit reached more than 35,000 million USD, with imports amounting to 74,114 million compared to exports of 38,934 million. This shift marks a turning point: from being a net exporter of hydrocarbons, Mexico has progressively become a net importer of petroleum products, weakening the external channel as a source of fiscal revenues and replacing it with a structure more dependent on domestic consumption. The shift of the trade balance into deficit has implications not only for the balance of payments but also for the sustainability of a fiscal model that has historically depended on the energy export capacity as a direct source of public financing[5].

Figure 4. *Mexico's Oil Exports and Imports (million USD; 1990–2023).*



Source: Own elaboration based on data by Banco de México (2024).

Finally, Figure 5 directly illustrates the shift of the fiscal channel from exports to the domestic market by comparing the evolution of oil exports (in Mexican pesos) with Pemex's domestic sales. Until the mid-2010s, both indicators showed relatively parallel trajectories, with a

[5] Through an input-output model, Guevara *et al.* (2021) show that substituting energy imports with domestic production might raise GDP by up to 2.5% and generate around 146 thousand additional jobs, whereas the collapse of extraction and refining –meeting demand through imports– would trigger a contraction of nearly 7% of GDP and the loss of more than 350 thousand jobs. These results confirm that Mexico's transition toward greater dependence on energy imports not only alters the trade balance, as illustrated in Figure 4, but also entails macroeconomic vulnerabilities of considerable magnitude.

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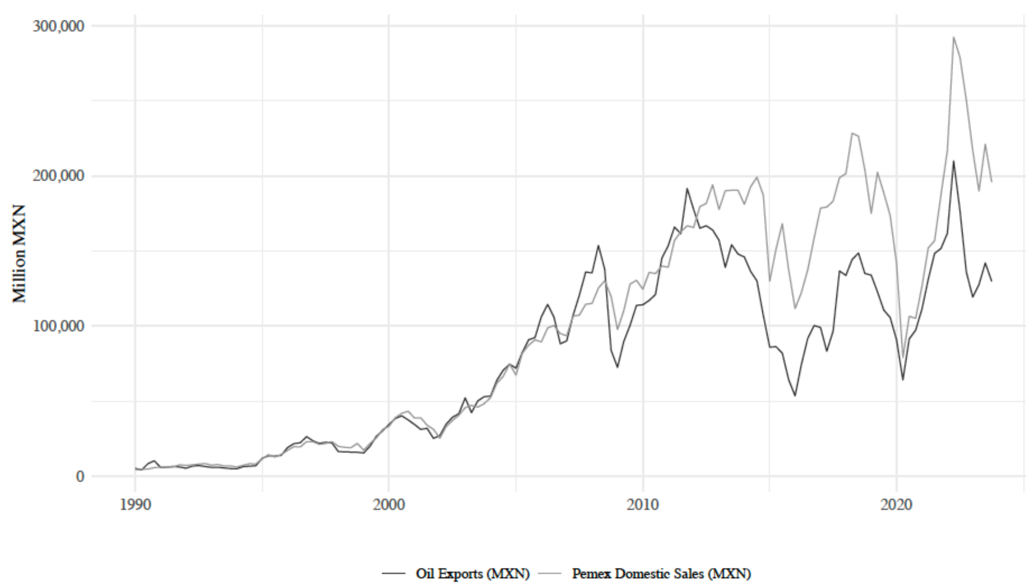
slight predominance of exports as the dominant component. However, starting with the effective implementation of the energy reform and the gradual liberalization of fuel prices, domestic sales have consistently surpassed exports in value terms.

This new scenario has fiscal, distributive, and energy policy implications, as it reduces the direct dependence of oil revenues on international crude prices but introduces greater indirect sensitivity through the design of the IEPS. Instead of capturing rents via exports, the state obtains revenues from domestic fuel consumption, whose prices –although formally liberalized– remain subject to fiscal intervention. This turns the domestic price into a tool of economic policy rather than a mere reflection of the global market. It also underscores the need to understand the structural relationships between production, commercial destination of crude oil, and fiscal revenues—an objective that is formally addressed in the following empirical sections.

Figure 5. *Oil exports and Pemex domestic sales (million pesos; 1990–2023).*

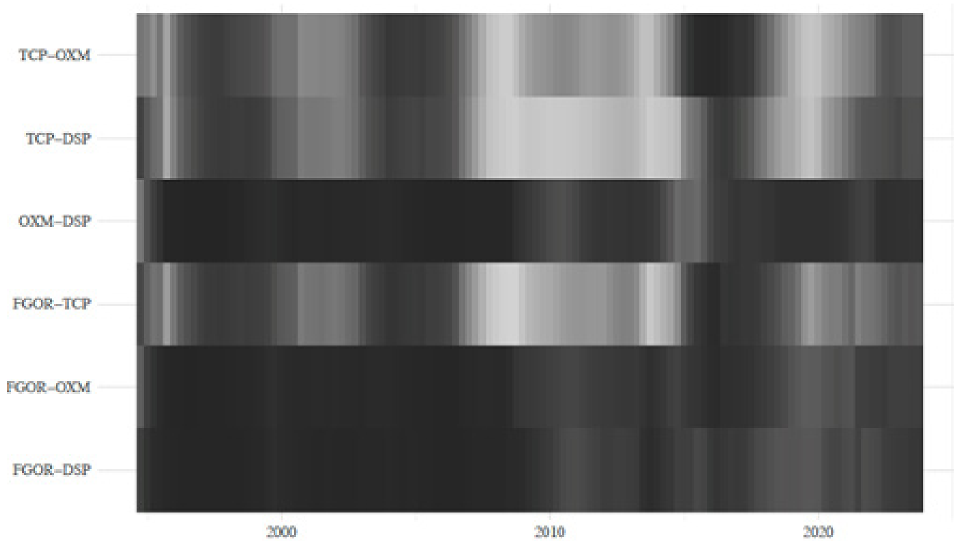


Source: Own elaboration based on data by Pemex (2024) and Banco de México (2024).

Figure 6 presents the rolling correlations among the main variables of Mexico's fiscal-energy system, calculated with a 20-quarter window to smooth short-term fluctuations and capture changes in association patterns. The results show that the relationship between federal government oil revenues (FGOR) and oil exports (OXM) remained high until the mid-2000s, with coefficients above 0.70, but fell sharply to negative values close to −0.8 in 2008-2014 and only recovered to moderate levels (0.5-0.7) in recent years. In contrast, the link between FGOR and domestic petroleum sales (DSP) went from practically null in the 1990s to peaks of 0.93-0.95 in

2015-2016, subsequently remaining within a positive range of 0.4-0.6. Crude oil production (TCP), on its part, showed an almost perfect correlation with exports in 1995-2005 (0.95-0.99), but declined to 0.37-0.70 after 2015; its association with domestic sales, also high in the initial period (0.9-0.99), fell in recent years to intermediate values of 0.6-0.8.

Figure 6. *Rolling correlations among revenues, production, exports, and domestic petroleum sales (20-quarter window; 1990-2023).*



Source: Own elaboration based on Pemex (2024) and Banco de México (2024) data.

Taken together, these figures confirm the progressive decoupling between the physical base of the system and the generation of fiscal oil revenues, reinforcing the need for empirical approaches capable of incorporating structural breaks, regime changes, and asymmetric adjustment mechanisms.

4. Methodology

The objective of this study is to analyze the joint long- and short-term dynamics between federal government oil-related budget revenues (FGOR) and a set of fundamental variables from the energy sector: total crude oil production, oil exports in Mexican pesos, and domestic sales of petroleum products (TCP, OXM, and DSP, respectively). All variables were transformed into natural logarithms to stabilize variances and facilitate interpretation in terms of elasticities. In line with previous literature, this study employs a vector error correction model (VECM), which is widely used to evaluate long- and short-term linkages in economies dependent on oil revenues. For example, Hamdi and Sbia (2013) show that this approach is suitable for capturing the dynamic relationship between oil revenues, public expenditure, and economic growth in Bahrain, thereby legitimizing its application to the analysis of Mexico's fiscal–energy architecture.

Additionally, a structural regime dummy (SRD) variable is incorporated to distinguish two stages within the fiscal-energy regime observed during the study period. This variable takes effect starting in the fourth quarter of 2016, a date selected based on the convergence of institutional and economic factors that mark a substantive shift in oil revenue dynamics. In particular, this quarter corresponds to the lowest point of the international price cycle that began in 2014 and also coincides with an abrupt decline in proven hydrocarbon reserves, implying a simultaneous deterioration in fiscal expectations and the sector's operational sustainability. The variable captures the onset of a new structural phase in the relationship between energy and public revenues. To model possible transition effects, an *SRD* is included in levels and at its first lag; lags of the remaining variables are incorporated within the standard VECM specification.

To ensure robust statistical inference in the presence of potential heteroskedasticity and serial dependence in the model's residuals, a moving block bootstrap (MBB) resampling procedure is implemented, following the methodological approach proposed by Künsch (1989). This approach groups observations into contiguous blocks, preserving short-term temporal dependence, and allows for the construction of valid confidence intervals in the presence of dynamic structures. Moreover, as shown by Brüggemann, Jentsch, and Trenkler (2016), the MBB proves particularly suitable in VAR/VECM models with conditional heteroskedasticity, as it ensures asymptotically valid inference in contexts where other bootstrap methods (wild or pairwise) tend to fail.

Model Specification

The estimated model cor

$$\Delta \mathbf{y}_t = \Pi \mathbf{y}_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta \mathbf{y}_{t-i} + \Phi \mathbf{x}_t + \mu + \varepsilon_t$$

"where y_t is the vector of endogenous variables integrated of order one", Δ denotes first differences, $\pi=\alpha\beta^{\top}$ is the long-run impact matrix, product of the adjustment coefficients (α) and the cointegration vectors (β), Γ_i represents the short-run dynamic matrices, x_t contains the exogenous variables and their lags, μ is a vector of constants, and ε_t is the vector of structural errors.

The vector of endogenous variables is defined as:

$$\mathbf{y}_t = \begin{bmatrix} \log(\mathrm{FGOR}_t) \\ \log(\mathrm{TCP}_t) \\ \log(\mathrm{OXM}_t) \\ \log(\mathrm{DSP}_t) \end{bmatrix}$$

and the set of exogenous variables consists of: $\mathbf{x}_t = \begin{bmatrix} SRD_t \\ SRD_{t-1} \end{bmatrix}$

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The estimation is performed with one lag in differences (*k=1*), including a constant and a deterministic trend in the system. A cointegration rank of *r=1* is imposed to capture the most relevant structural relationship among the variables, dominated by the response of FGOR to energy sector imbalances. The final form of the model includes a single cointegrating combination $\beta^{\top} y_{t-1}$ associated with its corresponding error correction term (ECT1).

To obtain confidence intervals that are robust to conditional heteroskedasticity and serial dependence in the residuals, bootstrap inference is applied using the moving block bootstrap method with B=1000 iterations. This procedure is implemented at the OLS regression stage on the first-difference equations, conditioned on the error correction term (ECT) and the exogenous variables.

The international oil price is not explicitly included as an independent variable, as its impact is internalized in the construction of the export (OXM) and domestic sales (DSP) variables, thereby avoiding the introduction of statistical noise associated with its high volatility.

The data are presented quarterly, covering the period from 1990 to 2023, and were obtained from official sources, including Pemex's institutional database and Banco de México.

Preprocessing and Unit Root Tests

To ensure the econometric validity of the model, unit root tests were applied using the Augmented Dickey-Fuller (ADF) test, with automatic lag selection according to the Akaike Information Criterion (AIC). The tests were performed on the series in levels, their natural logarithmic transformations, and their first differences to verify their order of integration. ADF specifications included a constant and deterministic trend (*regression = "ct"*) for levels and log-levels, and a constant (*regression = "c"*) for first differences.[6]

Table 1 reports the results of the ADF test on the original level series:

Table 1. *ADF test on original level series*

Variable	ADF Statistic	p-value	Stationary (5%)
FGOR	-2.1261	0.5315	No
TCP	-1.8906	0.6595	No
OXM	-3.1418	0.0966	No
DSP	-1.7208	0.7416	No

Source: Own elaboration.

As shown, none of the variables in their original levels reject the null hypothesis of a unit

[6] The selection of deterministic components follows the classical approach of Dickey and Fuller (1979), where inclusion of both constant and trend in levels and logs allows for the possible presence of deterministic components under the alternative hypothesis of stationarity. In first differences, the deterministic trend is removed by construction, so only a constant is included.

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root at the 5% significance level.

Table 2 presents the results after applying the natural logarithm to each series. Again, none of the log-transformed variables are stationary in levels.

Table 2. *ADF test on log-transformed series*

Variable	ADF Statistic	p-value	Stationary (5%)
LOG_FGOR	-1.3714	0.8691	No
LOG_TCP	-1.8710	0.6696	No
LOG_OXM	-2.1597	0.5126	No
LOG_DSP	-0.3587	0.9881	No

Source: Own elaboration.

Finally, when applying the ADF test on the first differences of these log-transformed series, all variables are found to be stationary with p-values below 0.05, as summarized below:

Table 3. *ADF test on first differences of logarithms*

Variable	ADF Statistic	p-value
ΔLOG_FGOR	–7.0129	0.0000
ΔLOG_TCP	–2.9662	0.0382
ΔLOG_OXM	–10.2854	0.0000
ΔLOG_DSP	–4.0159	0.0013

Source: Own elaboration.

These results confirm that all four variables are integrated of order one, $I(1)$. Regarding seasonality treatment, the FGOR series showed significant seasonality according to the Welch test and was therefore seasonally adjusted using the X-13ARIMA-SEATS method prior to the analysis.

5. Results

The Johansen cointegration test (Johansen, 1988) (see Table 4) suggests the presence of two long-term equilibrium relationships ($r=2$), as the null hypotheses of no cointegration ($r=0$) and at most one cointegrating relationship ($r=\leq 1$) are both rejected at the 5% significance level. The third hypothesis ($r=\leq 2$) is not rejected. This implies that there are at least two stable linear combinations among the variables in the long run, reflecting the economic equilibrium constraints between government oil revenues, crude oil production, oil exports, and domestic sales.[7]

Table 4. *Johansen cointegration test results (trace statistic)*

Null Hypothesis	Trace Statistic	Critical Value (5%)
r = 0	142.3	55.25
r = ≤ 1	53.68	35.01
r = ≤ 2	15.24	18.40

Source: Own elaboration.

The estimated equilibrium relationship is presented in Table 5, along with the dynamic adjustment coefficients (matrix α). The cointegrating vector is normalized with respect to FGOR and can be interpreted as a fiscal oil revenue equilibrium function as a function of production, exports, and domestic sales in the energy sector:

$$\mathrm{CI}_1 = \log(\mathrm{FGOR}) - 0.1191 \log(\mathrm{TCP}) - 0.5209 \log(\mathrm{OXM}) - 0.4514 \log(\mathrm{DSP})$$

Table 5. *Estimated cointegration (β) and adjustment (α) matrices*

Variable	Cointegration (β)	Adjustment (α)
LOG_FGOR	1.0000	-0.5307
LOG_TCP	-0.1191	0.0305
LOG_OXM	-0.5209	0.3698
LOG_DSP	-0.4514	0.2486

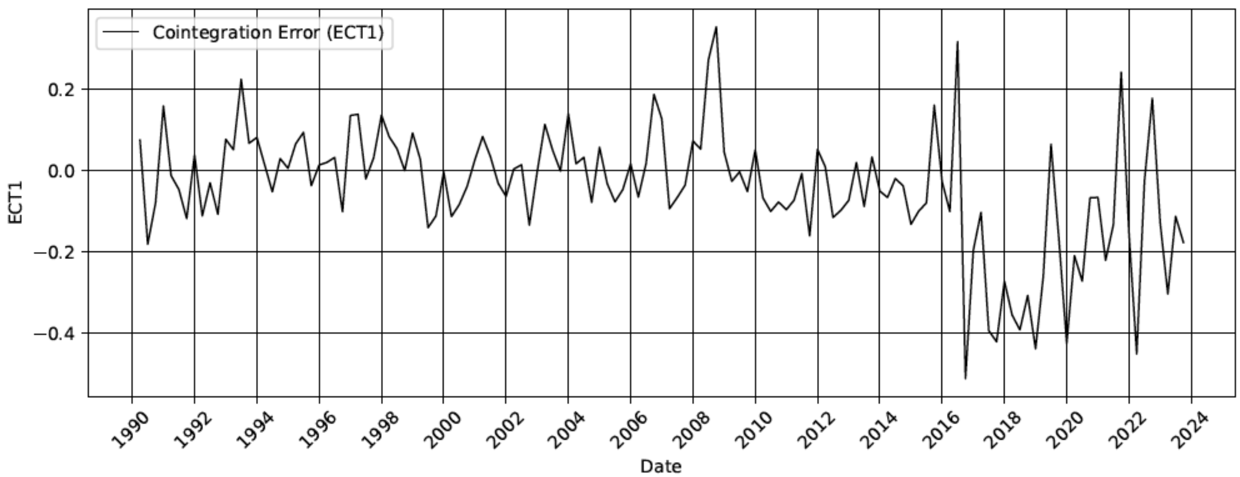
Source: Own elaboration.

A strong adjustment of FGOR to long-term disequilibria stands out, with a coefficient , implying that over 53% of the disequilibrium is corrected within a single period. OXM and DSP also exhibit significant adjustments, although at a slower pace. In contrast, crude oil production (TCP) shows a small coefficient that is not significantly different from zero, suggesting that it operates exogenously with respect to the fiscal adjustment mechanism. As documented by Martínez and Herrera (2021), Pemex's organizational structure and fiscal regime have induced an investment pattern highly concentrated in exploration and production, but without effective responsiveness to fiscal requirements. Furthermore, production has not been used as an adjustment instrument for budgetary imbalances, but rather as a passive rent source captured through predetermined duties and contributions, without explicit short-term fiscal feedback mechanisms.

[7] Although the test suggests *r=2* , the second estimated vector presents numerically unstable coefficients and does not generate significant dynamic adjustments. As documented in Appendix 1, the model is restricted to *r=1* to preserve economic interpretability and system parsimony.

Figure 7 shows the time evolution of the error correction term (ECT), illustrating its convergence toward the mean and the stability of the estimated equilibrium.

Figure 7. *Evolution of the Cointegration Error (ECT1)*



Source: Own elaboration.

As part of the residual diagnostics and model validation, standard tests were applied to assess the statistical quality of the residuals generated by the VECM system (see Table 6). Although normality is rejected for all series (Jarque-Bera test), the autocorrelation behavior is acceptable in most cases, and heteroskedasticity is clearly detected only in LOG_TCP.

Table 6. *Residual diagnostics: normality, autocorrelation, and heteroskedasticity*

Variable	JB p-value	LB (p=4)	ARCH (p=4)
LOG_FGOR	0.0010	0.0145	0.1627
LOG_TCP	0.0000	0.2913	0.0000
LOG_OXM	0.0000	0.7048	0.6090
LOG_DSP	0.0000	0.6743	0.0693

Source: Own elaboration.

These results reflect some deviations from the classical VAR model assumptions, particularly regarding normality and heteroskedasticity. Nevertheless, for statistical inference purposes, residual-based bootstrap was applied (Gonçalves and Kilian, 2004), allowing the estimation of standard errors and confidence bands robust to these issues. Thus, the conclusions regarding coefficient significance and system dynamics are statistically valid.

To evaluate the marginal short-term effects on each endogenous variable, the differenced equations of the system were estimated. Table 7 summarizes the estimated coefficients, standard errors, and the corresponding percentiles of the 95% confidence intervals.

Table 7. *Short-term coefficients with bootstrap percentile intervals (95%)*

Dependent Variable: LOG_FGOR	Coef.	SE	CI 2.5%	CI 97.5%
const	0.0299	0.0162	0.0011	0.0627
ECT1	0.4042	0.1251	0.1721	0.6551
SRD	-0.5445	0.1805	-0.9654	-0.2130
SRD_L1	0.6151	0.1763	0.3002	1.0576

Source: Own elaboration.

The coefficient of the error correction term (ECT1) is positive, statistically significant, and its confidence interval excludes zero, confirming the role of FGOR as the main adjustment variable in the dynamics toward long-run equilibrium. Likewise, the coefficients associated with the structural dummy indicate differentiated short-term effects following the regime shift: a negative contemporaneous impact and a positive lagged effect, suggesting a phase of institutional transition in the configuration of the fiscal-energy link. The final model specification excludes additional exogenous variables, such as U.S. industrial production, as they did not provide significant explanatory power in this equation.

The multivariate Portmanteau test confirms the absence of severe autocorrelation in the system. As shown in Table 8, the average p-values for lags 1 to 5 remain above 0.3, supporting the validity of the dynamic specification. Although from lag 6 onward some minimum p-values fall below 5%, the overall behavior remains acceptable.

Table 8. *Multivariate Portmanteau test: p-values by lag*

Lag (h)	Avg. p-value	Min. p-value
1	0.6575	0.4729
2	0.5943	0.1846
3	0.6741	0.2120
4	0.4212	0.0145
5	0.3764	0.0202
6	0.1954	0.0064
7	0.2521	0.0118
8	0.3054	0.0206

Lag (*h*)	Avg. p-value	Min. p-value
9	0.3340	0.0343
10	0.3018	0.0186
11	0.2874	0.0183
12	0.2076	0.0053

Source: Own elaboration.

To assess the system's stability over time, a structural break detection procedure (Bai and Perron, 2003) was applied based on the Bayesian Information Criterion (BIC). Table 9 summarizes the results for different specifications with 0 to 6 breaks.

Table 9. *Optimal number of structural breaks (BIC criterion)*

Number of Breaks (*k*)	RSS	BIC
0	2.99	-514.37
1	2.12	-536.46
2	2.00	-520.81
3	1.91	-502.91
4	1.86	-482.30
5	1.82	-460.93
6	1.77	-440.55

Source: Own elaboration.

The optimal number of breaks is one *(k=1*), with a substantial improvement in the BIC compared to the model without breaks. The estimated date of structural change is the third quarter of 2016, which coincides with several relevant transformations: the lowest point in the international oil price cycle, the sharpest decline in proven reserves, and the moment when the economic and institutional effects of the energy reform began to consolidate. This evidence supports the incorporation of dummy variables that parsimoniously capture this new fiscal-energy regime.[8]

Since no multiple breaks or severe instability were identified in the stability tests (CUSUM, CUSUMSQ), it is concluded that the VECM model exhibits a relatively stable structure throughout the period, adequately adjusting to the post-2016 regime.

The statistical validity of the cointegrating vector was confirmed through an ADF test applied to the residual of the estimated linear combination (CI1), whose statistic of –4.3292 (p-value

[8] See Appendix 2, where separate model estimations before and after 2016 are presented, including variations in the cointegration vectors and dynamic adjustment coefficients.

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= 0.0028) allows for rejection of the unit root null hypothesis, thus confirming the existence of a genuine long-run equilibrium between fiscal oil revenues and the fundamental variables of the energy sector, following Engle and Granger's (1987) criterion. This result, together with the significance of the error correction term (ECT), the dynamic stability of the system, and the consistency of the bootstrap estimators, supports the reliability of the selected specification. The incorporation of a structural variable activated in 2016, validated through break tests, allows the model to capture the regime shift in the fiscal-energy relationship.

Discussion of Results

The estimated results allow for a clear interpretation of the current architecture of Mexico's fiscal-energy link. Public oil revenues are not determined by the physical volume of extraction, but rather by the system's capacity to convert that production into capturable monetary flows through exports and domestic sales. This finding is not only empirically relevant, but also provides a key to understanding why oil revenues may fluctuate sharply even when production remains stable or even declines: what matters is not the number of barrels extracted, but how, where, and under what institutional conditions they are valorized. This distinction is fundamental in economies where crude oil ceases to be a mere physical commodity and becomes a fiscal asset subject to commercial intermediation, price policies, and tax design.

The dynamics observed in the model further confirm a persistent asymmetry in adjustment mechanisms: when the system deviates from its long-run equilibrium, it is fiscal revenue that responds—not the energy determinants. This behavior is far from trivial. It reveals that Mexico's institutional petroleum regime is designed to passively absorb sectoral conditions without directly intervening in them. Production, far from acting as a policy variable, operates as a rigid input, constrained by technical capacities, investment contracts, and operational restrictions that limit its responsiveness to fiscal pressures. The state does not extract more when revenues fall, nor does it reinforce its production platform during downturns; instead, it adjusts revenue according to the available valorization channel. This reactive logic shapes a form of fiscal dominance in which revenues follow rather than lead.

The structural break identified in 2016 deepens this pattern. Rather than being a mere statistical breakpoint, it marks the beginning of a new phase in which the external channel –historically dominant as a source of oil rents– loses centrality, and the budget increasingly relies on flows generated by domestic fuel consumption. This transition, far from implying a disconnection from the global cycle, exposes public finances to new forms of sensitivity: it is no longer the barrel price that directly determines revenue, but rather how the government manages the domestic price through IEPS, subsidies, and fiscal adjustment bands. Energy policy thus becomes a space for intermediation between international signals and domestic fiscal pressures, without necessarily having a productive anchor to support that transition. The result is a more vulnerable, less predictable fiscal link, increasingly conditioned by discretionary decisions.

In this shift from external to internal rents, highly relevant distributive implications can also be observed. Whereas under the previous regime the rent captured by the State was derived primarily from crude oil exports –that is, from transfers originating with external buyers– in the more recent stage the burden falls on domestic consumers through the IEPS and domestic fuel prices, thereby introducing regressive effects on household disposable income. Added to this is Pemex's corporate organization as a conglomerate of subsidiaries, where fiscal capture historically concentrated on the exploration and production branch through levies such as the Shared Utility Duty, while its refining and commercialization subsidiaries operated under differentiated schemes of subsidies and price regulation. Furthermore, the 2014 energy reform facilitated the incorporation of private actors into import, transportation, and commercialization activities, opening new channels for rent appropriation and fragmenting its governance. Taken together, these elements underscore that the transition from exports to domestic consumption is not merely a change in the accounting origin of revenues, but a distributive and institutional reconfiguration of the fiscal-energy nexus in Mexico.

This behavior has clear parallels with other hydrocarbon-exporting countries. In contexts such as Nigeria or Ecuador, it has been documented that oil revenues depend less on production volumes than on the fiscal and commercial regime that channels their wealth[9]. In these cases, as in Mexico, public spending tends to expand during booms without strengthening the operational base that sustains revenue, generating procyclical cycles that are difficult to reverse during contractions.[10] However, Mexico's particularity lies in its attempt to transition toward an internal valorization of oil rents without yet consolidating a robust institutional framework to support it. Fiscal capture of domestic consumption remains mediated by volatile subsidies, political decisions regarding IEPS, and a declining production platform.

What emerges from the model is not just a statistical snapshot, but a structural portrait of a fiscal system critically dependent on the energy environment, yet lacking active mechanisms to influence it. Fiscal revenues behave as outcome variables rather than stabilization instruments. Production, in turn, remains an operational constant with no revenue elasticity. And public policy, rather than anticipating cycles, follows them. This configuration has profound implications for fiscal rule design, expenditure sustainability, and the state's ability to face energy transition scenarios without compromising its budgetary stability. The evidence shows that, beyond prices or volumes, it is the institutional architecture of the valorization channel that ultimately defines the strength—or fragility—of the fiscal-energy link.

[9] See Ossowski *et al.* (2008).

[10] Villafuerte and López-Murphy (2010) document, for example, that during the 2003-2008 oil boom, producing countries' governments expanded public spending as revenues increased, while the 2009 price collapse once again forced adjustments onto fiscal balances without structural operational changes.

Conclusions

This study provides structural evidence that the Mexican state's oil rent does not depend directly on extraction volumes but on the institutional channels that allow such extraction to be converted into public revenue. Fiscal collection is anchored in resource valorization rather than physical exploitation. Exports and domestic sales represent the true fiscal transmission vectors, while production operates as an inert variable, constrained by technical limitations, long-term investment decisions, and the absence of operational fiscal feedback. This finding reflects an institutional pattern in which public revenues do not guide energy policy but instead adjust passively to sector conditions.

The incorporation of a structural variable starting in 2016 precisely captures the regime shift associated with the energy reform and the international oil price collapse. This turning point highlights the exposure of public finances to external shocks when the fiscal framework lacks robust stabilizing rules (Baunsgaard *et al.*, 2012). Empirical evidence shows that, following this break, revenue became more sensitive to international prices – not because the state gained greater control over production, but because the design of the IEPS –and its role as a fiscal buffer– became the main adjustment channel, intensifying the system's vulnerability to global cycles.

This pattern is not unique to Mexico. Comparative studies have documented how, in oil economies such as Nigeria or Ecuador, fiscal policy reacts to exported rent but fails to modify its productive base (Ossowski *et al.*, 2008). Where credible fiscal rules are absent, spending tends to expand during booms and contract sharply during price downturns, reproducing procyclical cycles that are difficult to reverse (Villafuerte and López-Murphy, 2010). In Mexico's case, although instruments such as the Budget Revenue Stabilization Fund (FEIP) and annual oil hedges exist, their use has been discretionary and insufficient to shield the budget from energy price swings (Baunsgaard *et al.*, 2012).

Recent literature suggests that governments tend to moderate spending when facing greater price uncertainty or when rules require saving a portion of the rent and spending only its future returns — the "bird-in-the-hand" approach (El Anshasy and Bradley, 2012). However, the effectiveness of such schemes critically depends on institutional quality. Where institutions are weak, oil rent tends to feed fiscal fragility or corruption; where they are strong, it can serve as a vehicle for sustained growth (Arin and Braunfels, 2018).

In this context, the results of the present study highlight three key areas for action. In terms of fiscal rules, it is essential to anchor expenditure sustainability to the non-oil primary balance, adopting conservative assumptions and progressively delinking the current budget from energy rents (Villafuerte and López-Murphy, 2010; Baunsgaard *et al.*, 2012). In terms of instruments, redesigning the FEIP under automatic and transparent criteria is a priority to prevent discretionary use and reinforce its role as an intertemporal buffer (Ossowski *et al.*, 2008). From a sectoral strategy perspective, it is necessary to advance domestic value-added integration, strengthening fiscal capture across export and domestic consumption circuits—since producing more does not guarantee collecting more if tax design and the valorization regime do not accompany it (Ossowski *et al.*, 2008).

The estimated model not only maps how oil rent flows into the treasury but also identifies why this flow remains vulnerable. Unless the fiscal-energy contract is redesigned with a countercyclical perspective and strong institutional foundations, public policy will remain exposed to the inertia of the oil cycle. In the face of a global energy transition and a declining productive base, shielding public finances is not merely a technical issue: it is a minimal condition for fiscal sovereignty.

In this scenario, it is also pertinent to raise a forward-looking reflection: how can the fiscal–energy nexus be strengthened in a context of transition toward clean energies and the decline of the oil platform? Beyond short-term fiscal instruments, the structural challenge lies in redefining the role of Pemex as an integrated energy company rather than solely an oil company. Such a transition would allow for the diversification of public revenue sources into new energy value chains, reduce dependence on crude oil, and articulate an institutional framework capable of sustainably capturing emerging rents. Within this logic, the discussion on energy resource governance cannot be limited to the capture of oil rent but must be broadened toward a fiscal design capable of accompanying the sector's productive transformation and shielding public finances in a scenario of climate change and progressive decarbonization. Comparative experience shows that producing countries face significant fiscal risk if they do not harness current rents to finance the transition: Ankrah *et al.* (2023), in the case of Ghana, find that growth in fossil fuel production reduces the expansion of renewable energies and that a shock in global crude demand can translate into substantial fiscal losses. This evidence suggests that for Mexico, strengthening Pemex under a diversified energy mandate is not only desirable from an environmental perspective, but necessary to sustain fiscal stability in the medium term.

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Appendix 1: Evaluation of Cointegration Vectors Estimated Under

The Johansen cointegration test based on the trace statistic suggests the presence of two long-run relationships at the 5% significance level. To evaluate this possibility, the model was estimated with rank , allowing for the extraction of two cointegrating vectors () and their corresponding dynamic adjustment coefficients ().

Table 10. *Estimated cointegration vectors (β), normalized with respect to LOG_FGOR*

Variable	β_1 (CI1)	β_2(CI2)
LOG_FGOR	1.0000	1.000000e+00
LOG_TCP	-0.0000	5.576867e+15
LOG_OXM	1.0968	7.575165e+16
LOG_DSP	-2.1422	-7.917464e+16

Source: Own elaboration.

Table 11. *Dynamic adjustment coefficients (α) for each cointegration vector*

Variable	α_1 (ECT1)	α_2 (ECT2)
LOG_IGGOB	-0.5713	0.0782
LOG_PRODCRUD	0.0270	-0.0023
LOG_EXPMXN	0.3605	-0.0406
LOG_VTAINT	0.1967	-0.0104

Source: Own elaboration.

Both combinations were evaluated using the ADF unit root test. The results are shown in Table 12.

Table 12. *Dynamic adjustment coefficients (α) for each cointegration vector*

Variable	α_1 (ECT1)	α_2 (ECT2)
LOG_FGOR	-0.5713	0.0782
LOG_TCP	0.0270	-0.0023
LOG_OXM	0.3605	-0.0406
LOG_DSP	0.1967	-0.0104

Source: Own elaboration.

Although CI2 is stationary (p = 0.0031), the estimated coefficients of vector () exhibit magnitudes on the order of to , reflecting severe numerical instability. Moreover, the dynamic adjustment coefficients () are close to zero in all equations, indicating that the system does not react to disequilibria defined by that combination.

In contrast, the first vector (CI1), while only marginally significant at the 10% level when estimated under , presents interpretable coefficients and a robust adjustment vector, particularly in the LOG_FGOR and LOG_OXM equations.

When a VECM is estimated with a cointegration rank greater than necessary, the system may generate linear combinations whose economic relevance or numerical stability is limited. This occurs because the model identifies a higher-dimensional cointegration space and distributes information across multiple vectors, even if some do not represent substantive relationships among the variables. In the present case, restricting the model to a single cointegrating vector () yields a more representative long-run equilibrium combination: the estimated coefficients are stable, the adjustment dynamics are clear, and the error correction term contributes significantly to the system's explanation. This specification concentrates the relevant information into a single structural relationship, avoiding distortions from additional vectors that add no explanatory value.

The second cointegrating vector (CI2) is therefore discarded due to its lack of economic interpretation and dynamic relevance. The final specification adopts , focusing the analysis on a single stable equilibrium relationship between fiscal oil revenues and the energy sector variables.

Appendix 2: Structural Changes in the Fiscal–Energy Relationship: Analysis Before and After 2016

The segmented estimation results of the VECM confirm the existence of a structural change in the relationship between government oil revenues (LOG_FGOR) and their energy determinants, which materializes around the third quarter of 2016. This breakpoint was identified through the Bai–Perron test applied to the cointegration error term (ECT). Table 13 summarizes the main parameters estimated before and after the break: the cointegration vectors (β), adjustment speeds (), and the immediate impact of the ECT on LOG_FGOR.

Table 13. *Estimated cointegration and adjustment vectors before and after 2016*

Variable	β Pre-2016	β Post-2016	α Pre-2016	α Post-2016
LOG_FGOR	1.0000	1.0000	–0.5870	–0.8937
LOG_TCP	–0.1467	0.1350	–0.0338	0.0460
LOG_OXM	–0.6614	–0.6894	0.3462	0.4833
LOG_DSP	–0.2892	–0.6097	–0.0791	0.1509
ECT on LOG_FGOR			0.0096	0.4533
Bootstrap CI 95%			[–0.2619, 0.2956]	[0.0043, 0.8683]

Source: Own elaboration.

As observed, the composition of the β vector undergoes a significant rebalance. Prior to 2016, the long-run relationship was dominated by oil exports in pesos (LOG_OXM), which retain a strong weight in both sub-periods, and by crude oil production (LOG_TCP), whose initially negative coefficient reverses after the break. In contrast, the coefficient associated with domestic petroleum product sales (LOG_DSP) increases in magnitude, suggesting a relative strengthening of the internal channel within the fiscal revenue generation system. This points to a structural transformation: government oil revenues begin to depend more on domestic flows while still maintaining some external trade influence.

The adjustment dynamics also change. While in the pre-2016 regime only LOG_FGOR actively corrected disequilibria (α≈-0.59), in the post-break period, both LOG_OXM and LOG_DSP also participate actively in the correction mechanism. This distributed dynamic suggests a transition from a pure fiscal equilibrium to a more complex fiscal-commercial interaction.

Finally, the estimated ECT coefficient on LOG_FGOR changes qualitatively. Prior to 2016, its effect is statistically null (the confidence interval includes zero), whereas after the break it becomes significant at the 95% level. This supports the idea that, under the new regime, fiscal revenues respond more directly to energy fundamentals and correct disequilibria more efficiently.