Who Bears Oil Price Risk? Fuel-Pricing Rules and Sovereign Risk Reallocation in an Emerging Market

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Abstract

Does rule-based import-parity fuel pricing stabilize exchange rates in commodity-dependent economies? We exploit Brazil's October 2016 transition from administered fuel pricing to import-parity pricing (PPI) as a discrete policy regime change to identify the effects of pricing rules on exchange rates and sovereign risk. The central finding is a sign reversal in the fuel-CDS relationship across regimes. Under administered pricing, higher oil prices reduce sovereign spreads through a commodity-windfall channel. Under PPI, the same shock widens spreads, reflecting a reallocation of oil-price risk from the sovereign balance sheet to consumers and firms. This reallocation compresses the fiscal-uncertainty amplification channel and produces large reductions in aggregate volatility. In the pre-COVID sample, real effective exchange-rate volatility falls by 64% and sovereign CDS spread volatility falls by 75%, despite PPI increasing the pass-through elasticity of domestic fuel prices to the Brent benchmark from 0.10 to 0.46. Local projection estimates show that cumulative responses of exchange rates and CDS spreads to fuel-price shocks are 40–60% smaller under PPI, with the CDS response turning negative at horizons beyond eighteen months. A battery of robustness tests, including placebo windows, pre-trend diagnostics, structural break tests, and comparative specifications exploiting fuel versus nonfuel commodity prices, indicates that the stabilization reflects the pricing-regime change rather than broader macroeconomic conditions. The May 2023 reversal of PPI confirms this interpretation: transmission coefficients returned to their pre-reform structure while the fiscal expenditure framework remained in place. The evidence is consistent with a credibility-based interpretation in which predictable pricing rules dampen policy uncertainty and risk-premium amplification. The exchange rate gains greater exposure to global commodity fundamentals under PPI, but the removal of discretionary intervention risk dominates, producing lower aggregate volatility.

Keywords: fuel prices; volatility; pass-through; commodity; country risk; exchange rate.

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1 Introduction

Fuel prices are both politically salient and macroeconomically consequential. In developing countries, governments frequently intervene in fuel markets through subsidies, price caps, or administrative controls, aiming to shield consumers from international commodity price volatility (Kpodar and Imam, 2021). While such policies can smooth short-run price fluctuations, they entail fiscal costs, distort energy consumption, and introduce uncertainty about the timing and magnitude of discretionary adjustments (Clements et al., 2013a). The macroeconomic implications of these policies remain poorly understood, particularly regarding their effects on exchange rates and sovereign risk premia—the channels most consequential for commodity-exporting emerging markets, where fuel pricing shapes both fiscal sustainability and terms-of-trade dynamics.

This paper studies how fuel-pricing regimes shape exchange-rate and sovereign-risk dynamics by exploiting Brazil's October 2016 transition from administered pricing to an import-parity pricing rule (PPI) as a discrete institutional change. Under administered pricing (2011–2016), the state-controlled oil company Petrobras held domestic fuel prices persistently below international benchmarks. For instance, by 2013, wholesale gasoline prices were roughly 30% below Gulf of Mexico import parity, generating mounting corporate losses and heightened fiscal stress (Khanna et al., 2016). Following a political transition and Petrobras's financial crisis, Brazil adopted PPI in October 2016, committing to align domestic prices with international benchmarks and thereby removing the discretionary component of fuel-price determination. The reform was subsequently reversed in May 2023, when Petrobras returned to a hybrid discretionary framework, providing a second institutional break that allows the identification strategy to exploit both the adoption and the removal of the pricing rule.

The macroeconomic implications of replacing administered pricing with a rule-based import-parity regime are theoretically ambiguous. Closer domestic-international price alignment may amplify volatility by feeding oil shocks into inflation expectations, monetary responses, and fiscal risk perceptions. Alternatively, rule-based pricing may dampen volatility by reducing fiscal uncertainty, eliminating speculative anticipation of politically timed adjustments, and allowing commodity price movements to operate as automatic stabilizers through the terms-of-trade channel. Whether credibility gains or market-exposure costs dominate is an open empirical question that our policy experiment is designed to answer.

Using monthly data from January 2003 to May 2023, we document that the PPI reform altered the mechanism through which oil shocks reach the exchange rate and sovereign risk. The central finding is a sign reversal in the fuel-CDS relationship across regimes. Under administered pricing, higher oil prices are associated with lower sovereign spreads, approximately 316 basis points per unit increase in log Brent, consistent with a commodity-windfall channel in which rising prices improve Petrobras's upstream revenues and the sovereign's net fiscal position by more than the associated increase in downstream subsidy costs. Under PPI, the same shock is associated with wider CDS spreads of approximately 188 basis points: once domestic prices adjust to international benchmarks, oil price increases raise inflation and political pressure for discretionary intervention, costs that investors price into sovereign spreads. This sign reversal reflects a reallocation of oil-price risk from the sovereign balance sheet to consumers and firms. By compressing the pricing wedge, PPI eliminates the fiscal-uncertainty amplification channel and activates the direct commodity-currency channel.

These changes in the conditional response of CDS spreads to oil shocks coincide with large reductions in unconditional volatility. The sovereign risk channel under administered pricing amplified any source of uncertainty, not only oil shocks, through the anticipation of discretionary interventions. Once PPI removed that anticipation channel, aggregate volatility fell substantially even though the exchange rate became more responsive to oil fundamentals. In the pre-COVID sample (2003:03–2020:02), REER volatility falls from 0.196 to 0.071, a decline of 64%, and sovereign CDS spread volatility falls from 209 to 53 basis points, a decline of 75%, despite PPI increasing the pass-through elasticity of domestic fuel prices to the Brent benchmark from 0.10 to 0.46, contrary to the standard prediction that liberalization amplifies external shocks. Cupom cambial volatility, a market-based measure of onshore dollar funding conditions distinct from sovereign credit risk, falls by 67% over the same period. Local projections confirm that transmission attenuation is gradual and persistent: cumulative REER responses are 34–68% smaller under PPI across horizons up to twelve months, and CDS responses are attenuated by 17–47% over the same window. Beyond eighteen months, the PPI-era CDS response turns negative, consistent with the long-run commodity-currency mechanism prevailing once fiscal-uncertainty amplification is removed.

The identification strategy rests on two politically driven institutional breaks, whose timing was determined by factors unrelated to exchange-rate dynamics. The October 2016 adoption of PPI followed Petrobras's financial distress and a contemporaneous change in federal government. Contemporaneous policy statements emphasized corporate governance and fiscal sustainability, with no reference to exchange-rate objectives. The May 2023 reversal reflected political pressure to shield consumers from elevated global fuel prices under a new administration and predated by three months a separate overhaul of Brazil's fiscal expenditure framework, a timing difference that permits separation of the fuel-pricing channel from concurrent changes in fiscal rules. Once PPI was abandoned, the pass-through elasticity collapsed from 0.61 to −0.18, the fuel-REER coefficient returned to its pre-reform structure ($F = 0.62$, $p = 0.43$ for equality with the pre-PPI value and $p < 0.001$ for equality with the PPI value), and the CDS-fuel relationship reversed sign, all while the fiscal expenditure framework remained in place, isolating the fuel-pricing regime as the operative channel.

Several additional pieces of evidence support this interpretation. Structural break tests locate the parameter shift in the fuel-exchange-rate relationship at September 2016, one month before the formal PPI implementation date and five months after the political transition in May 2016. A placebo exercise assigning a fictitious PPI period to October 2013–May 2015 yields a statistically insignificant interaction coefficient. A commodity channel test confirms that the post-2016 break is substantially larger for fuel than for non fuel prices; the fuel effect is nearly three times the magnitude of the non-fuel effect and the difference is statistically significant. A pre-trend estimated over the full pre-PPI period predicts a strengthening of fuel-driven depreciation pressures after 2016, so that the estimated attenuation under PPI is conservative. The 2015 episode of large discretionary price adjustments under administered pricing provides a final anchor: those adjustments coincided with a doubling of REER volatility and a doubling of mean CDS spreads, establishing that predictability of the pricing rule, and not price adjustment per se, drives the stabilization documented here.

Our analysis makes three contributions. First, we provide quasi-experimental evidence on the macroeconomic effects of fuel-pricing institutions, connecting an underexplored policy instrument, the design of state-owned enterprise pricing rules, to exchange-rate and sovereign-risk dynamics. Although a large literature quantifies the fiscal costs of fuel subsidies (Kpodar and Imam, 2021; Clements et al., 2013b) and discusses energy-price reform in emerging markets

(Bettarelli et al., 2024; Clements et al., 2013a), evidence on how pricing regimes reshape macroeconomic transmission is limited. The two-sided experiment, covering the adoption and subsequent abandonment of PPI, provides identification of regime effects that a one-time reform cannot deliver.

Second, we document a risk-reallocation mechanism linking fuel-pricing discretion to sovereign risk amplification. Under administered pricing, oil-price shocks transmit to exchange rates primarily through fiscal uncertainty and risk-premium channels. This finding complements commodity-currency research (Chen and Rogoff, 2003; Cashin et al., 2004; Ferraro et al., 2015) by showing that domestic pricing institutions govern the mapping from global oil shocks to exchange-rate dynamics, and complements work on emerging-market risk premia (Neumeyer and Perri, 2005; Uribe and Yue, 2006; Bernoth and Herwartz, 2021) by identifying fuel-pricing discretion as a policy-relevant driver of sovereign risk volatility and documenting the sign reversal in the CDS-fuel relationship across regimes.

Third, Petrobras equity-market data provide direct micro-level evidence on the policy-uncertainty channel. Under administered pricing, Petrobras equity volatility moves strongly with Brent price volatility; under PPI, this sensitivity effectively disappears while Petrobras's co-movement with the broad equity market rises, indicating that the firm's risk profile shifted from oil-market uncertainty to economy-wide fundamentals. The frequency of idiosyncratic return surprises falls by 44% under PPI. The convergence of macro-level volatility compression and firm-level risk reduction illustrates that institutional commitment can deliver macroeconomic stabilization through credibility mechanisms, without reserve management, capital controls, or countercyclical fiscal programs.

The remainder of the paper is organized as follows. Section 2 describes the institutional background and reviews the related literature. Section 3 presents the conceptual framework. Section 4 outlines the empirical design. Section 5 reports the main results, including price alignment (Section 5.1), transmission mechanisms (Section 5.2), dynamic responses from local projections (Section 5.4), volatility reduction (Section 5.3), identification tests Section 5.5), and the 2023 reversal (Section 5.6). Section **??** reports additional robustness tests, and Section 6 concludes.

2 Background

2.1 Institutional Setting: Brazil's Fuel Pricing Regimes

Brazil's fuel pricing policy has evolved through shifts between market-based and administratively controlled regimes, reflecting changing political and macroeconomic priorities related to inflation control, fiscal sustainability, and energy security. This institutional trajectory provides the historical context necessary to understand the policy transition we study and to interpret our empirical findings.

Petrobras, established in 1953 as Brazil's national oil company, occupies a unique position at the intersection of corporate activity and public policy. The federal government retains majority control (50.26% of voting shares as of 2024), and Petrobras operates more than 80% of domestic refining capacity, making it the dominant price setter in wholesale fuel markets (Nascimento Filho et al., 2021; Hallack et al., 2020). This market structure allows the government to influence retail fuel prices indirectly through Petrobras's ex-refinery pricing decisions, even in the absence of formal price controls. Moreover, as the country's largest taxpayer—remitting approximately BRL 270 billion in 2024, or about 7% of federal tax revenues (Petrobras, 2024)—Petrobras's financial performance has direct fiscal implications, creating a feedback loop between fuel pricing policy and sovereign risk perceptions.

Brazil's fuel pricing regime has evolved through a sequence of liberalization and retrenchment. The 1997 Petroleum Law (Law No. 9,478) formally dismantled Petrobras's legal monopoly and set in motion a gradual liberalization process completed by 2002 (Bridgman et al., 2011). Although prices were formally liberalized, market-based pricing proved fragile. Beginning in the early 2010s, a combination of high international oil prices and rising domestic inflation renewed political pressures to contain fuel prices. Between 2011 and 2015, the federal government increasingly relied on Petrobras as an instrument of price stabilization, directing the company to hold domestic fuel prices below import-parity levels. By 2013, wholesale gasoline prices were approximately 30% below U.S. Gulf Coast import-parity benchmarks (Khanna et al., 2016).

To mitigate the financial strain imposed on Petrobras, the government temporarily eliminated federal fuel excise taxes in 2013–2014. These measures, however, only partially offset revenue losses, and implicit subsidy costs remained substantial. Figure 1 traces petroleum subsidy outlays from 2010 to 2022, showing that spending peaked at over US$10 billion in 2011 before declining sharply—by roughly 45%—by 2015, as fiscal pressures intensified. This period of rising fiscal costs and mounting distortions set the stage for the subsequent shift toward rule-based pricing.

The fuel subsidy regime reflected a political–economic trade-off that ultimately proved destabilizing. By shielding consumers from rising international oil prices, the government sought to contain inflation and social discontent, but at the cost of transferring mounting losses to Petrobras. As these losses accumulated, Petrobras recorded a substantial net loss in 2015 (Almeida et al., 2015), coinciding with Brazil's sovereign credit downgrade and a deep economic recession.

Fuel subsidies affected macroeconomic stability through several interrelated channels. Financing the subsidies imposed an increasing fiscal burden, while the discretionary nature of price controls created uncertainty about the timing and magnitude of inevitable adjustments, encouraging speculative capital flows and exchange-rate pressure. At the same time, suppressing domestic fuel prices weakened the economy's automatic stabilizers. For a commodity-exporting country such as Brazil, higher oil prices would normally improve fiscal balances and support the currency; under the subsidy regime, this adjustment mechanism was muted as domestic prices failed to respond to international price movements.

In October 2016, following a political transition and a deep financial crisis at Petrobras, the incoming management announced a decisive shift in fuel pricing policy. Petrobras would adopt import-parity pricing (PPI), committing to set ex-refinery prices according to international benchmarks, transportation costs, and a risk-adjusted margin (Nascimento Filho et al., 2021). Unlike earlier, short-lived liberalization attempts, PPI introduced a public, rule-based framework that explicitly tied domestic fuel prices to international oil markets and the BRL/USD exchange rate, thereby constraining political discretion. Although the precise adjustment frequency and the calculation of risk premia were not fully disclosed,[1] the reform marked a clear institutional

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[1] For contemporaneous reporting on the policy, see: https://noticias.uol.com.br/comprova/ultimas-noticias/2023/05/24/entenda-as-politicas-de-precos-da-petrobras.htm

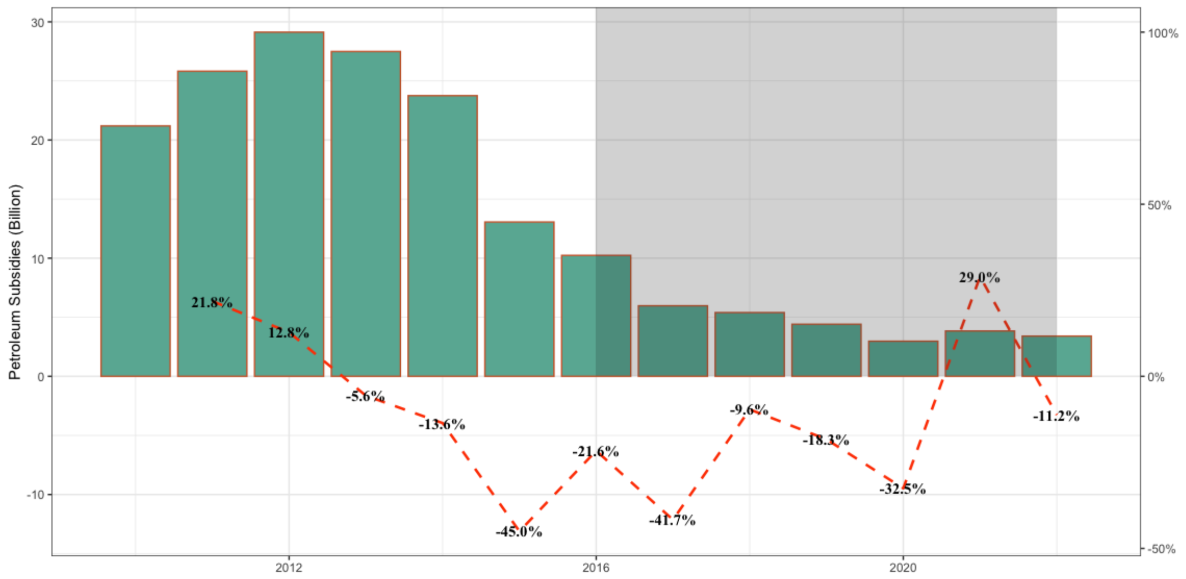

Figure 1: Estimates of subsidies to petroleum in Brazil. The shaded region in gray depicts the PPI policy period and the red line depicts the percentage variation betweeb years. Source: OECD, IEA, IMF, UN, World Bank

break from administered pricing and provides the discrete policy change that underpins our identification strategy.

The PPI regime was tested by two major episodes that highlight its political-economy constraints. First, in May 2018, a surge in global oil prices translated into rapid domestic fuel price increases, triggering a nationwide truckers' strike that disrupted economic activity. In response, the government capped diesel price increases and reduced the frequency of adjustments, temporarily weakening the automatic price-adjustment mechanism embedded in PPI (Palazzi et al., 2022). Second, in 2022, the Russia–Ukraine conflict pushed international oil prices to decade highs, again generating political pressure for price intervention. These episodes underscore that even rule-based pricing regimes remain vulnerable to political override during periods of extreme price movements.

In May 2023, Petrobras formally announced the termination of PPI and a return to a hybrid pricing framework with greater managerial discretion. The reversal was driven by political-economy considerations—most notably, pressure to shield domestic consumers from international price volatility—rather than by contemporaneous macroeconomic conditions. The six-and-a-half-year duration of PPI (October 2016–May 2023) therefore defines a well-delineated policy regime that provides substantial time-series variation to estimate regime effects. Moreover, narrative identification based on the political and institutional context surrounding both the introduction and the termination of PPI supports treating the reform as an institutionally exogenous policy change, enabling causal inference on the short-run effects of fuel pricing rules on fuel prices and exchange-rate dynamics.

Our identification strategy builds on a narrative account that treats the shift from administered pricing to PPI as a policy change driven by Petrobras's fiscal distress and a contemporaneous political transition, rather than by expectations of future exchange-rate dynamics. Several features of the historical record support this interpretation. First, the reform coincided with senior management turnover following the Operation Car Wash corruption scandal, pointing to governance and political considerations as the primary drivers of the policy change. Second, as shown in Figure 1, petroleum subsidy outlays had already begun to decline in 2015, well before any change in the exchange-rate regime. Third, contemporaneous policy statements emphasized fiscal sustainability and corporate governance reform, with no reference to exchange-rate stabilization objectives.

We bolster this narrative evidence with formal tests for differential pre-treatment dynamics, including tests on lead coefficients in our event-time specifications, reported in Section 5.5. Taken together, the sharp October 2016 break and the subsequent 2023 reversal—both rooted in political-economy considerations—define a clean identification strategy for studying how fuel pricing rules affect exchange-rate dynamics. The next section develops a simple analytical framework to organize the empirical analysis of this regime shift.

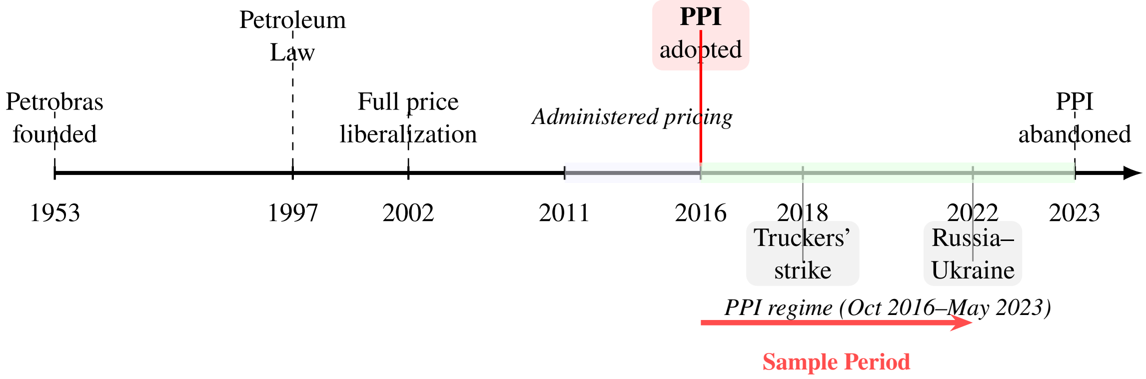

Figure 2: Timeline of Brazil's Fuel Pricing Policy Evolution

Notes: The figure shows key institutional changes in Brazil's fuel pricing regime. The shaded green area indicates the Import Parity Pricing (PPI) period (October 2016–May 2023). The red arrow marks our sample period (October 2016–May 2023). Policy events appear above the timeline; external shocks appear below.

2.2 Commodity Currencies and Fuel Pricing Regimes

A large literature documents that commodity prices play a central role in explaining exchange-rate movements in resource-rich economies (Chen and Rogoff, 2003; Cashin et al., 2004), and that oil price shocks affect both bilateral and real effective exchange rates (Ferraro et al., 2015). Far less is known about how domestic fuel-pricing institutions mediate this transmission in emerging markets by reallocating shocks across public and private balance sheets. We argue that under administered pricing, insulating domestic fuel prices from international benchmarks weakens the contemporaneous commodity–currency relationship and shifts oil price shocks onto the public sector through implicit subsidies. This reallocation operates through two reinforcing channels: heightened quasi-fiscal exposure and increased policy uncertainty regarding the timing and magnitude of eventual price adjustments. As a consequence, oil price shocks affect exchange rates primarily through the sovereign-risk channel, amplifying risk premia beyond what would be implied by the terms-of-trade channel alone.

By contrast, a rule-based import-parity regime—such as Brazil's October 2016 PPI—reestablishes the link between domestic and international prices, allowing commodity price movements to transmit directly through the terms-of-trade channel. At the same time, predictable pricing rules reduce policy uncertainty and constrain quasi-fiscal exposure, thereby attenuating the amplification of exchange-rate fluctuations through sovereign risk premia.

The commodity-currency literature documents a systematic co-movement between real commodity prices and real exchange rates in economies with substantial commodity exports. Chen and Rogoff (2003) show that commodity price indices predict real exchange rates for Australia, Canada, and New Zealand. Extending this analysis to a broader cross-section, Cashin et al. (2004) study 58 countries over 1980–2002 and find robust evidence of long-run cointegration in roughly one-third of cases; within this group, commodity prices account for a sizable share of long-run real exchange-rate variation. Bodart et al. (2012) further demonstrate that the strength of this relationship increases with the share of commodity exports, consistent with Dutch Disease mechanisms in which resource booms appreciate real exchange rates through spending effects.

For Brazil, Kohlscheen (2014) shows that a commodity price basket weighted by export shares explains approximately 60% of real effective exchange rate (REER) movements between 2000 and 2012, with oil, iron ore, and soybeans as the dominant contributors. The discovery of pre-salt oil reserves strengthened this relationship: Brazil transitioned from a net oil importer in the early 2000s to a self-sufficient producer after 2007, fundamentally altering the exchange rate's exposure to international oil price fluctuations. This evolution motivates our focus on domestic fuel-pricing policy, which governs whether and how international oil price movements transmit to the domestic economy and, in turn, shape exchange-rate dynamics in commodity-exporting emerging markets.

A critical yet understudied question is how administrative versus market-based fuel-pricing regimes mediate the transmission of international oil shocks. Kpodar and Imam (2021) analyze 96 countries over 1970–2014 and show that fuel subsidies attenuate the transmission of international prices to domestic fuel prices: heavily subsidized economies exhibit pass-through rates of only 20–40%, compared with 60–80% in liberalized markets. This insulation creates a fiscal–monetary trade-off. While administrative pricing can stabilize inflation in the short run, it does so by accumulating subsidy costs that ultimately threaten fiscal sustainability.

Plante (2014) formalize this mechanism in a small open-economy DSGE model, showing that fuel subsidies distort relative prices, misallocate labor across sectors, and reduce aggregate welfare. In their framework, welfare losses arise primarily from price misalignment rather than from the particular financing mix used to fund subsidies. Brazil's experience prior to PPI is consistent with these predictions. Between 2011 and 2016, Petrobras reported sustained losses while domestic fuel prices were held below import parity, coinciding with a deterioration in sovereign credit conditions (Nascimento Filho et al., 2021). The adoption of PPI reversed this regime, restoring price alignment and eliminating relative price distortions. At the same time, it increased domestic exposure to international oil price volatility, creating the central transmission channel we examine. Under PPI, oil price shocks feed into consumer prices, elicit monetary policy responses, and propagate through sovereign risk premia to exchange rates.

A second mechanism operates through sovereign risk premia. Fuel-pricing regimes can affect CDS spreads through two margins with opposing predictions. Under administered pricing (pre-2016), keeping domestic fuel prices below import parity shifts oil-price risk onto Petrobras and, ultimately, the public sector. Persistent pricing gaps create quasi-fiscal losses and contingent liabilities (implicit or explicit support to Petrobras), and the timing of discrete adjustments is politically negotiated. This combination can raise sovereign-risk volatility by increasing uncertainty about future fiscal costs and policy interventions. Under rule-based import-parity pricing (PPI), the pricing gap narrows and subsidy-like transfers become less likely, which reduces the fiscal tail risk borne by the sovereign. At the same time, stronger pass-through from global oil prices to domestic fuel prices can raise inflation volatility and political pressure for discretionary relief—as illustrated by the May 2018 truckers' strike—which may increase perceived reversal risk and, in principle, widen CDS spreads in response to oil shocks. In financially integrated emerging markets, changes in sovereign risk premia transmit quickly to capital flows and exchange-rate pressures (Cerutti et al., 2019), implying that the net exchange-rate effect depends on whether the fiscal/credibility channel or the inflation/reversal-risk channel dominates.

Brazil's inflation-targeting framework further shapes these dynamics. In a flexible inflation-targeting regime, central banks respond to both inflation deviations and exchange-rate movements (Aizenman et al., 2011). With stronger fuel-price pass-through under PPI, oil shocks can affect CDS premia through inflation and political-economy risks, while reduced quasi-fiscal exposure can dampen CDS sensitivity by lowering expected fiscal support. We therefore treat the sign and magnitude of the CDS response as an empirical question, and test whether the PPI regime reallocates oil-price risk away from the sovereign.

Sovereign CDS spreads provide a market-based measure of country risk and serve as the central mediating variable in our framework. Calice and Zeng (2021) demonstrate that the sovereign CDS term premium predicts exchange rates at horizons spanning one quarter to two years. Feng et al. (2021) find bidirectional spillovers: exchange rate shocks affect CDS dynamics, while CDS movements predict subsequent exchange rate changes. For emerging markets, Uribe and Yue (2006) and Longstaff et al. (2011) show that sovereign spreads respond to both domestic fundamentals and global risk factors, suggesting that country risk mediates the transmission of external shocks to currencies. Bernoth and Herwartz (2021) extend this evidence across 16 emerging market economies, revealing that currency depreciation increases sovereign risk through the financial channel (higher debt service burdens in foreign currency terms), with this transmission channel dominating offsetting effects through net exports.

This literature motivates using sovereign CDS spreads as a market-based measure of country risk and a potential mediator between external commodity shocks and exchange-rate dynamics. In our setting, fuel-pricing institutions determine whether oil shocks load primarily onto (i) quasi-fiscal liabilities and policy uncertainty under administered pricing, or (ii) domestic inflation and political-economy pressures under rule-based import-parity pricing (PPI). These forces have opposing implications for CDS and exchange-rate transmission. Stronger pass-through under PPI may increase the sensitivity of inflation and monetary policy to oil shocks, potentially strengthening oil–CDS comovement. Conversely, by narrowing pricing gaps and reducing contingent fiscal exposure and intervention uncertainty, PPI may weaken the sovereign-risk amplification channel even as it strengthens the direct commodity-currency channel. We therefore treat the sign and magnitude of the CDS response, and its role in exchange-rate transmission, as empirical questions. Section 5 tests whether the post-2016 regime reallocates oil-price risk away from the sovereign and attenuates the contribution of sovereign risk premia to exchange-rate movements. Empirically, this implies a horse race between an inflation/reversal-risk channel (which strengthens oil–CDS comovement under PPI) and a fiscal/credibility channel (which weakens CDS amplification under PPI).

3 Conceptual Framework

This section develops the economic logic linking fuel-pricing institutions to exchange-rate dynamics. The central mechanism is a pricing wedge between domestic fuel prices and import parity. Under administered pricing, this wedge generates fiscal exposure that amplifies sovereign risk and exchange-rate volatility. Import-parity pricing compresses the wedge, which attenuates the fiscal channel and activates direct commodity pass-through to domestic prices.

3.1 The Pricing Wedge and Sovereign Risk

Consider a small open economy where the real exchange rate q_t is determined by external fundamentals, interest differentials, and a country risk premium. Modified uncovered interest parity implies

$$i_t - i_t^* = \mathbb{E}_t[\Delta s_{t+1}] + \rho_t, \tag{1}$$

where s_t is the log nominal exchange rate (domestic per foreign), i_t and i_t^* are domestic and foreign interest rates, and the composite risk premium decomposes as $\rho_t = \rho_t^{\text{cred}} + \rho_t^{\text{liq}}$. The credit component ρ_t^{cred} reflects sovereign default risk; the liquidity component ρ_t^{liq} reflects onshore dollar funding conditions and market segmentation.

We proxy ρ_t^{cred} with CDS spreads on sovereign debt. For ρ_t^{liq}, let cc_t denote the *cupom cambial*, the onshore USD-implied interest rate derived from domestic rates and the FX forward market,

$$cc_t \equiv i_t - (f_t - s_t), \tag{2}$$

where f_t is the log forward rate. The liquidity premium is then

$$\rho_t^{\text{liq}} \equiv cc_t - i_t^*. \tag{3}$$

Under covered interest parity (CIP), $f_t - s_t \approx i_t - i_t^*$, so $cc_t \approx i_t^*$ and $\rho_t^{\text{liq}} \approx 0$. Deviations from CIP therefore map directly into ρ_t^{liq}, making it a measure of the onshore-offshore basis and the cost of hedging BRL/USD exposure. We align maturities by pairing the 360-day cupom cambial futures contract (DDI) with the one-year U.S. Treasury yield, so that ρ_t^{liq} reflects currency-specific liquidity and segmentation premia free of term-structure differences.

To connect pricing policy to fiscal exposure, let P_t^{oil} denote the USD price of crude oil and let M_t collect per-liter components such as refining margins, freight, and taxes. The import-parity level price of domestic fuel is

$$P_t^{\text{PPI}} \equiv S_t\, P_t^{\text{oil}}\, M_t, \tag{4}$$

where $S_t \equiv e^{s_t}$ is the BRL/USD nominal exchange rate and $M_t \equiv e^{m_t}$ maps crude prices into delivered domestic fuel prices. Let P_t^{fuel} denote the observed domestic level fuel price. The pricing wedge is

$$W_t \equiv P_t^{\text{PPI}} - P_t^{\text{fuel}}, \tag{5}$$

with $W_t > 0$ representing an implicit subsidy and $W_t < 0$ representing an implicit tax or margin capture. In logs, the corresponding wedge is $w_t \equiv p_t^{\text{PPI}} - p_t^{\text{fuel}}$, and for small gaps $W_t \approx P_t^{\text{fuel}} \cdot w_t$.

Under administered pricing, the government sets p_t^{fuel} through discretionary interventions with little reference to contemporaneous international prices. Pass-through is low, so the elasticity κ

in $\Delta p_t^{\text{fuel}} = \kappa \Delta p_t^{\text{PPI}} + u_t$ is close to zero, and the wedge is large and volatile. Under import-parity pricing, domestic prices adjust according to a rule tied to international benchmarks, pass-through rises, and the wedge compresses, though taxes, margins, and adjustment lags prevent complete convergence to unity.

The wedge creates fiscal exposure through the state oil company's balance sheet. When international prices rise and domestic prices are held fixed, Petrobras sells fuel below replacement cost, generating operating losses proportional to sales volume. Let Q_t denote domestic fuel consumption and ϑ the state's effective exposure to Petrobras through ownership, dividends, and guarantees. The parameter ϑ is slow-moving, governed by the state's ownership stake; PPI reduces fiscal exposure by compressing w_t rather than by altering ϑ. In the empirical specifications, Q_t and ϑ are slow-moving and absorbed into the scale of the estimated coefficient χ below; what matters for identification is variation in the wedge w_t across regimes. The fiscal transfer required to cover wedge-induced losses is

$$\Omega_t = \vartheta\, Q_t\, W_t, \tag{6}$$

and the sovereign's debt dynamics include this exposure,

$$B_{t+1} = (1 + r_t)B_t + G_t - T_t + \Omega_t. \tag{7}$$

Sovereign credit risk depends on both expected and uncertain future fiscal pressure from the wedge,

$$\rho_t^{\text{cred}} = \bar{\rho} + \chi\, \mathbb{E}_t[\Omega_{t+1}] + \psi\, \text{Var}_t[\Omega_{t+1}] + \eta_t, \qquad \chi, \psi > 0. \tag{8}$$

The first channel (χ) captures the level of expected fiscal transfers; the second (ψ) captures uncertainty about their timing and magnitude, which is elevated when adjustments are discretionary and irregular. This variance term motivates the inclusion of realized fuel-price volatility as a control in all empirical specifications, computed each month as the standard deviation of daily Brent log returns.

To derive the response of sovereign risk to an oil shock, we normalize by conditioning on the USD oil price innovation and abstracting from the mechanical effect of the contemporaneous exchange rate S_t and markup M_t on the import-parity price; that is, we hold S_t and M_t fixed within the shock definition. Under this normalization, $\partial W_t / \partial p_t^{\text{oil}} \propto (1 - \kappa)$, and the response of sovereign credit risk is approximately

$$\frac{\partial \rho_t^{\text{cred}}}{\partial \Delta p_t^{\text{oil}}} \approx \chi\, \vartheta\, Q_t \cdot (1 - \kappa) > 0. \tag{9}$$

When pass-through κ is low, oil shocks transmit strongly to sovereign risk through the wedge. When pass-through is high, this channel is attenuated.

3.2 Exchange Rate Transmission Across Regimes

An oil-price shock affects q_t through three components: (i) a terms-of-trade channel, (ii) an inflation and monetary-policy channel operating through domestic fuel pass-through, and (iii) a fiscal-risk channel arising from the pricing wedge. The net impact is

$$\frac{\partial q_t}{\partial \Delta p_t^{\text{oil}}} = \beta^{\text{ToT}} + \kappa\gamma + (1 - \kappa)\delta. \tag{10}$$

For a commodity exporter, the terms-of-trade channel typically implies $\beta^{\text{ToT}} < 0$. The pass-through coefficient γ is a reduced-form object with ambiguous sign a priori, as the inflationary effect of higher fuel prices and the subsequent monetary-policy response can move q_t in either direction. The effective fiscal-risk contribution $(1 - \kappa)\delta$ is implied by the wedge mechanism in equation (9).

The regime determines which balance sheet absorbs the shock on impact. Under administered pricing, κ is low and the wedge absorbs international price movements; the resulting quasi-fiscal exposure can raise sovereign-risk premia and amplify exchange-rate volatility beyond what the terms-of-trade channel alone would imply. Under PPI, κ rises and adjustment shifts from the wedge into domestic prices. The effective fiscal-risk contribution $(1 - \kappa)\delta$ attenuates, not because δ changes as a structural parameter, but because the weight $(1 - \kappa)$ on the fiscal channel shrinks as pass-through increases.

This framework clarifies why the fuel-CDS relationship need not have a stable sign. Under administered pricing, two forces operate in opposite directions. Higher oil prices may reduce CDS via a windfall channel (stronger Petrobras cash flow and an improved fiscal position), yet raise CDS via the wedge channel (wider w_t and higher expected transfers Ω_t). Under PPI, the wedge channel weakens as κ rises, but pass-through raises inflation and political pressure for discretionary intervention, a reversal risk that investors may price into sovereign spreads. The net sign of the fuel-CDS relationship across regimes is therefore determined empirically, which we test in Section 5.2.

The framework delivers four testable predictions.

(i) Pass-through from international to domestic fuel prices should be higher under PPI ($\kappa_{\text{PPI}} > \kappa_{\text{pre}}$).

(ii) The effective fiscal-risk contribution $(1 - \kappa)\delta$ should attenuate under PPI, with the sign of the fuel–CDS relationship determined by which channel dominates in each regime.

(iii) Cumulative exchange-rate responses to oil shocks should be smaller at medium horizons under PPI. At extended horizons, responses should converge across regimes as the long-run equilibrium reasserts itself.

(iv) The post-2016 break should be specific to fuel prices and distinguishable from concurrent movements in non-fuel commodity benchmarks.

4 Empirical Strategy

4.1 Fuel Price Alignment

Before testing macroeconomic transmission, we verify that PPI increased alignment between domestic and international fuel prices, the necessary condition for the mechanism in equation (9). We estimate the regime-dependent pass-through equation,

$$p_t^D = \kappa_0 + \kappa_1 \,\text{PPI}_t + \kappa_2 \, p_t^B + \kappa_3 \,(p_t^B \times \text{PPI}_t) + \upsilon_t, \tag{11}$$

where the pass-through elasticity is κ_2 pre-PPI and $\kappa_2 + \kappa_3$ under PPI, with the theory predicting $\kappa_3 > 0$.

Equation (11) is estimated in levels because domestic and international fuel prices are cointegrated in both regimes. Engle-Granger tests reject no cointegration at the one percent level in each subperiod (see Table 1: $\tau = -4.32$ pre-PPI; $\tau = -4.02$ under PPI). We quantify alignment through three metrics: the correlation between p_t^D and p_t^B, the pass-through elasticity κ, and the relative volatility of domestic versus international price changes. As robustness, we estimate alignment in BRL terms, replacing p_t^B with $p_t^{B,\mathrm{BRL}} \equiv s_t + p_t^B$, which corresponds to the import-parity price in equation (4). As robustness, we estimate alignment in BRL terms, replacing p_t^B with $p_t^{B,\mathrm{BRL}} \equiv s_t + p_t^B$, which corresponds to the import-parity price in equation (4).

4.2 Risk Premium Specification

To establish the fuel price–sovereign risk nexus predicted by equation (9), we estimate how fuel market conditions affect Brazil's risk premium. The baseline specification is

$$\mathrm{CDS}_t = \alpha + \lambda\,\mathrm{CDS}_{t-1} + \theta_p\, p_t^{\mathrm{fuel}} + \theta_\sigma\, \sigma_t^{\mathrm{Brent}} + \theta_w\, \sigma_t^{\mathrm{gap}} + \boldsymbol{\psi}'\mathbf{X}_{t-1} + \varepsilon_t, \tag{12}$$

where $\sigma_t^{\mathrm{Brent}}$ is Brent realized volatility, σ_t^{gap} is the rolling standard deviation of the domestic–international fuel price gap $\mathrm{gap}_t \equiv p_t^D - p_t^B$, and $\mathbf{X}_{t-1}$ contains lagged non-fuel commodity prices, lagged VIX, and the lagged interest-rate differential. We include both volatility measures to separate global oil-market uncertainty ($\sigma_t^{\mathrm{Brent}}$, which may also capture global risk appetite) from the policy-specific uncertainty implied by the wedge mechanism (σ_t^{gap}, which measures the variability of Petrobras's implicit subsidy exposure). The ψ term in equation (8) predicts $\theta_w > 0$ through the policy uncertainty channel. The sign of θ_p reflects the horse race between the windfall and wedge channels and is treated as an empirical object.

The regime-dependent specification allows these effects to differ across pricing regimes,

$$\begin{aligned}\mathrm{CDS}_t = {}& \alpha_0 + \alpha_1\,\mathrm{PPI}_t + \lambda\,\mathrm{CDS}_{t-1} \\ & + \theta_{p,0}\, p_t^{\mathrm{fuel}} + \theta_{p,1}\,(p_t^{\mathrm{fuel}} \times \mathrm{PPI}_t) \\ & + \theta_{\sigma,0}\,\sigma_t^{\mathrm{Brent}} + \theta_{\sigma,1}\,(\sigma_t^{\mathrm{Brent}} \times \mathrm{PPI}_t) \\ & + \theta_{w,0}\,\sigma_t^{\mathrm{gap}} + \theta_{w,1}\,(\sigma_t^{\mathrm{gap}} \times \mathrm{PPI}_t) + \boldsymbol{\psi}'\mathbf{X}_{t-1} + \varepsilon_t.\end{aligned} \tag{13}$$

Equation (9) implies that raising pass-through κ reduces the effective fiscal-risk contribution $(1-\kappa)\delta$, so we expect $|\theta_{p,0} + \theta_{p,1}| < |\theta_{p,0}|$ under PPI. Under PPI, the gap itself compresses and its volatility declines, so σ_t^{gap} mechanically falls. The interaction $\theta_{w,1}$ therefore captures whether the sensitivity of CDS to residual gap volatility also changed with the regime. As robustness, we estimate parallel specifications using the cupom cambial spread ρ_t^{liq} from equation (3), which captures currency liquidity risk distinct from sovereign credit risk.

4.3 Exchange Rate Specification

We study exchange-rate transmission at two complementary horizons. Local projections, reported in Section 4.4, trace the dynamic effect of Brent shocks on q_t under each pricing regime without conditioning on domestic pricing decisions. A levels specification characterizes long-run comovement between fuel prices and the real exchange rate. Unit root and cointegration diagnostics, reported in Appendix C, yield mixed results, and we treat the levels relationship as an approximation rather than an established equilibrium condition.

For the long-run relationship, we estimate

$$q_t = \alpha + \beta_2\, p_t^{\text{fuel}} + \beta_3\, (p_t^{\text{fuel}} \times \text{PPI}_t) + \beta_4\, \sigma_t^{\text{Brent}} + \beta_5\, (\sigma_t^{\text{Brent}} \times \text{PPI}_t) + \beta_6\, \sigma_t^{\text{gap}} + \mathbf{\Gamma}'\mathbf{X}_{t-1} + \varepsilon_t, \tag{14}$$

where $\mathbf{X}_{t-1}$ contains lagged VIX, lagged non-fuel commodity prices, and the lagged interest-rate differential. The policy-uncertainty proxy σ_t^{gap} is the trailing twelve-month standard deviation of the domestic–international fuel price gap, $\sigma_t^{\text{gap}} \equiv \text{sd}(\text{gap}_{t-12}, \ldots, \text{gap}_{t-1})$, and is predetermined by construction. We include both volatility measures to separate global oil-market uncertainty (σ_t^{Brent}, which may also reflect global risk appetite) from the policy-specific uncertainty directly implied by the wedge mechanism (σ_t^{gap}, which measures the variability of Petrobras's implicit subsidy exposure).

As robustness, we estimate equation (14) by dynamic OLS (DOLS), augmenting the regression with leads and lags of Δp_t^{fuel} to address potential endogeneity in the levels specification (Stock and Watson, 1993). We also report an error-correction specification,

$$\Delta q_t = \phi\, \hat{\varepsilon}_{t-1} + \gamma_2\, \Delta p_t^{\text{fuel}} + \gamma_3\, (\Delta p_t^{\text{fuel}} \times \text{PPI}_t) + \gamma_4\, \sigma_t^{\text{Brent}} + \gamma_5\, (\sigma_t^{\text{Brent}} \times \text{PPI}_t) + \gamma_6\, \sigma_{t-1}^{\text{gap}} + \mathbf{\Gamma}'\Delta\mathbf{X}_{t-1} + \nu_t, \tag{15}$$

where $\hat{\varepsilon}_{t-1}$ is the lagged deviation from the estimated long-run relation and $\sigma_{t-1}^{\text{gap}}$ enters lagged to preserve predetermination. The ECM separates equilibrium adjustment (through ϕ) from short-run dynamics (through γ_2, γ_3), clarifying why short-run innovations can display different signs from long-run comovement, consistent with Section 3.2.

The regime-specific pass-through coefficients are

$$\frac{\partial q_t}{\partial p_t^{\text{fuel}}} = \begin{cases} \beta_2, & \text{pre-PPI} \\ \beta_2 + \beta_3, & \text{PPI.} \end{cases} \tag{16}$$

The key prediction for volatility is $\beta_5 < 0$. PPI attenuated the sensitivity of q_t to global oil-market uncertainty by removing discrete policy-jump risk. We estimate on the pre-COVID sample (2003:03–2020:02), which defines the cleanest PPI regime window and excludes the COVID-19 shock from the baseline. In specifications where p_t^{fuel} enters as a regressor, we report OLS as the primary estimator. Brent-based 2SLS is reported as a sensitivity check for reverse causality rather than as a structural causal estimate, for the reasons discussed in Section 4.5.

Neither the interaction coefficient $\hat{\beta}_3$ nor the local projection estimates require cointegration for consistent estimation. The interaction term identifies a change in slope across regimes rather than a long-run levels equilibrium, and the LP specification differences the outcome variable and uses a first-differenced shock, both of which are valid under I(1) processes. Cointegration tests are reported in Appendix C for transparency.

4.4 Local Projections

To trace the full dynamic adjustment path, we estimate local projections following Jordà (2005). Let $x_t \equiv \Delta \log(P_t^{\text{Brent}})$ denote the monthly Brent price innovation. For each horizon

$h = 0, 1, \ldots, H$, we estimate

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h x_t + \gamma_h (x_t \times \text{PPI}_t) + \delta_h' \mathbf{X}_{t-1} + \varepsilon_{t+h}, \tag{17}$$

where $y_t \in \{q_t, \log(\text{CDS}_t), \rho_t^{\text{liq}}, p_t^{\text{fuel}}\}$. The coefficient β_h captures the cumulative response under administered pricing; $\beta_h + \gamma_h$ captures the response under PPI. Controls $\mathbf{X}_{t-1}$ enter lagged one period with respect to the shock to ensure they are predetermined. We use lag-augmented local projections following Montiel Olea and Plagborg-Møller (2021), adding lags of Δy_t and x_t to absorb serial correlation directly rather than through kernel-based variance estimation. All inference uses Eicker-Huber-White standard errors; results are robust to HAC alternatives with Andrews bandwidth selection.

The framework predicts horizon-dependent responses. At short horizons, the fiscal-uncertainty channel in equation (9) may dominate under administered pricing, producing depreciation and CDS widening that attenuate once PPI raises pass-through. At longer horizons, the commodity-currency channel is expected to prevail in both regimes as the long-run commodity-currency relationship reasserts itself, motivating the extended-horizon results in Appendix A.

4.5 Identification

The empirical strategy rests on the interaction between external oil-price variation and the discrete change in fuel-pricing institutions introduced in October 2016 and partially reversed in May 2023. The central identifying assumption is that global oil-price movements are orthogonal to Brazilian macroeconomic conditions, so that differential responses across pricing regimes reflect institutional rather than macroeconomic differences. Brent crude prices serve as the primary shock variable because the Brazilian regulatory framework ties domestic fuel pricing directly to the international Brent benchmark: the National Petroleum Agency (ANP) calculates the Reference Oil Price from monthly Brent averages, and the PPI formula aligns Petrobras's domestic prices with import-parity costs derived from the same benchmark. Variation in Brent therefore constitutes the natural source of exogenous cost variation in this institutional setting rather than an econometric choice. All specifications control for lagged non-fuel commodity prices (IMF Non-Energy Commodity Index) and lagged VIX, which absorb the main global demand and risk-appetite components of oil price variation. The oil supply news shock z_t of Känzig (2021) serves as a demand-purged validation instrument, as described in Appendix B.

The fiscal expenditure ceiling (*teto de gastos*), introduced in December 2016, is a potential confound given its near-simultaneous adoption with PPI. Fiscal credibility channels, however, operate through the level of risk premia rather than through their sensitivity to commodity shocks. The identification here rests on transmission coefficients—how outcomes respond to oil-price variation—and this distinction addresses the fiscal confound directly. Section 5.6 documents that these coefficients reverted to their pre-reform structure after PPI was abandoned in May 2023, while the fiscal framework remained in place, providing a direct test of this argument. The most direct test of this argument is the May 2023 reversal of PPI itself. The fiscal expenditure framework remained in place when PPI was abandoned, so any reversion in transmission coefficients after May 2023 is attributable to the fuel-pricing regime. Section 5.6 shows that the pass-through elasticity collapsed from 0.61 to -0.18 after abandonment, the fuel-REER coefficient returned to its pre-reform structure ($F = 0.62$, $p = 0.43$ for equality with the pre-PPI value), and the CDS-fuel relationship reversed sign, all while the fiscal framework remained unchanged. This timing asymmetry between the two policy changes, three months apart, provides available evidence that the transmission results reflect the fuel-pricing regime. Appendix D reports supporting evidence from Petrobras equity markets, where the regime-dependent factor structure of realized volatility provides a direct measure of the policy-uncertainty premium the framework predicts.

Throughout the empirical analysis, two complementary specifications are estimated. The baseline conditions only on lagged predetermined variables—lagged non-fuel commodity prices, lagged VIX, and the lagged interest-rate differential—and captures the total effect of fuel prices on the exchange rate through all channels. The mechanism specification augments the baseline with contemporaneous CDS spreads and the lagged cupom cambial. Since these variables are endogenous outcomes of fuel-price shocks in the conceptual framework, conditioning on them absorbs part of the transmission mechanism. Any attenuation in the fuel-price coefficients in the mechanism specification quantifies transmission operating through sovereign-risk and currency-liquidity channels. The baseline is treated as the primary specification and the mechanism specification as diagnostic.

4.6 Data

We construct a monthly time series for Brazil spanning January 2003 to May 2023. We begin in 2003 to avoid the extreme exchange-rate volatility surrounding the 2002 presidential election and spillovers from Argentina's 2001 default, which generated exchange-rate dynamics largely unrelated to fuel-market conditions. The sample ends in May 2023, shortly after the Lula administration announced modifications to the PPI formula. We report results for both the full sample and a pre-COVID sample ending in February 2020, which we treat as the primary specification given the cleaner regime definition. The post-2003 period includes the 2008–09 Global Financial Crisis, the 2014–16 recession, and the COVID-19 pandemic. Macroeconomic and financial variables are obtained from the Central Bank of Brazil (BCB), Bloomberg, and the Bank for International Settlements (BIS). Retail fuel prices come from Brazil's National Agency of Petroleum (ANP).

The dependent variable is Brazil's real effective exchange rate (REER) from the BIS broad indices database. We define the log real effective exchange rate as $q_t \equiv -\log\left(\frac{\mathrm{REER}_t}{100}\right)$, so that increases in q_t represent real depreciation.

We use Brent crude oil as the international benchmark. The monthly Brent price $p_t^B \equiv \log(\overline{\mathrm{Brent}_t})$ is the arithmetic average of daily settlement prices of the ICE Brent front-month futures contract (USD/barrel) within month t, obtained from Bloomberg. For identification exercises, we also use the oil supply news shock series from Känzig (2021), which isolates revisions in expected future oil production using high-frequency price movements around OPEC announcements.

We construct a domestic fuel price index as a weighted average of retail prices for the three main fuels: $p_t^D \equiv \log\left(0.35P_t^{\mathrm{gas}} + 0.50P_t^{\mathrm{diesel}} + 0.15P_t^{\mathrm{ethanol}}\right)$, where weights reflect average consumption shares from ANP data and are held constant to avoid endogeneity (ANP, 2023). Retail prices are ANP's monthly survey series. In robustness checks, results are similar using gasoline-only prices and a log-weighted index $\sum_j \omega_j \log P_t^j$.

The PPI regime dummy is defined as:

$$\text{PPI}_t = \begin{cases} 0 & \text{if } t < \text{October 2016 (administered pricing)} \\ 1 & \text{if } t \geq \text{October 2016 (rule-based import-parity pricing)} \end{cases}$$

Petrobras announced PPI in October 2016, with implementation starting that month.

Brazil's fuel trade balance varies over time: the country transitioned from a net crude oil importer to a net exporter while remaining a persistent diesel importer. We construct a continuous net import intensity measure:

$$\text{NI}_t \equiv \frac{\text{Fuel Imports}_t - \text{Fuel Exports}_t}{\text{GDP}_t},$$

where fuel imports and exports (in USD) are obtained from ANP data and GDP is in current USD from BCB.[2] Positive values indicate net imports.

We control for standard determinants of the real exchange rate: the interest-rate differential $(r_t^{BR} - r_t^{US})$, where r_t^{BR} is the Selic target rate and r_t^{US} is the Federal Funds target rate; a non-fuel commodity price index (IMF Non-Energy); global risk aversion (CBOE VIX index); the cupom cambial spread (lagged one period), capturing domestic USD funding/hedging conditions; and the 5-year USD sovereign CDS spread (in basis points).

5 Results

The empirical findings are organized around the theoretical predictions in Section 3. Section 5.1 documents that PPI strengthened price alignment, consistent with the prediction that pass-through κ rises under rule-based pricing. Section 5.2 establishes that transmission mechanisms changed fundamentally; sovereign risk sensitivity shifted in the manner predicted by equation (9). Section 5.3 shows that macroeconomic volatility fell markedly. Section 5.4 reports dynamic responses of the REER and CDS spreads to oil price shocks across pricing regimes. Section 5.5 reports a battery of identification tests that establish fuel specificity. Section 5.6 analyzes the May 2023 reversal, which provides direct evidence that the transmission results reflect the fuel-pricing regime rather than concurrent fiscal developments.

5.1 Price Alignment

Price alignment statistics confirm that PPI strengthened the link between domestic and international fuel prices, as predicted by the framework. Table 1 reports alignment statistics for the pre-PPI period (2003:01–2016:09) and the PPI period (2016:10–2020:02). The correlation between domestic gasoline prices and the Brent benchmark rises from 0.31 under administered pricing to 0.69 under PPI. The pass-through elasticity from the bivariate regression $p_t^D = \kappa_0 + \kappa p_t^B + u_t$ increases from 0.10 to 0.46. Relative volatility—the ratio of the standard deviation of domestic price changes to that of Brent—rises from 0.18 to 0.40, indicating that domestic prices track international movements more closely while still exhibiting less than one-for-one adjustment.

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[2] We obtain BCB series using the R package *GetBCBData* (CRAN).

Table 1: Fuel Price Alignment: Pre-PPI vs. PPI

	Pre-PPI (2003:01–2016:09)	PPI (2016:10–2020:02)
Panel A: Price Alignment		
Correlation (domestic–Brent)	0.307	0.689
Pass-through elasticity ($\hat{\kappa}$)	0.104	0.459
Relative volatility ($\sigma_{\Delta p^D}/\sigma_{\Delta p^B}$)	0.178	0.397
Panel B: Macroeconomic Stability		
FX volatility ($\sigma_{\Delta q}$, annual)	16.2%	14.5%
CDS spread volatility	209 bp	53 bp
Mean CDS spread	255 bp	192 bp
Cupom cambial volatility	1.90 pp	0.63 pp
Panel C: Cointegration (Domestic–Brent)		
Engle-Granger τ	-4.32^{***}	-4.02^{***}

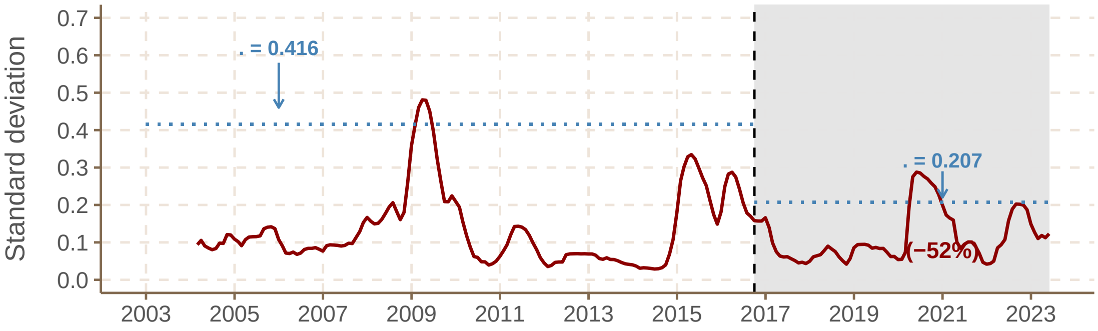
Notes: Panel A: Pass-through from bivariate regression $p_t^D = \kappa_0 + \kappa p_t^B + u_t$. Relative volatility is the ratio of standard deviations of monthly log changes. Panel B: FX volatility is standard deviation of monthly log changes in nominal exchange rate. Panel C reports cointegration between domestic fuel prices and Brent, not between the exchange rate and fuel prices; the latter is reported in Appendix C. Critical value (1%) = −3.90. $^{***}p < 0.01$.

Figure 3 displays the price gap $\text{gap}_t \equiv p_t^D - p_t^B$ over the sample period. The gap remained negative throughout, indicating that Brazilian consumers paid below-international prices under both regimes. The dynamics, however, differ considerably. During the administered pricing regime, the gap fluctuated between −4.0 and −2.5 as policymakers adjusted prices in response to fiscal pressures and political considerations. After the introduction of PPI, the gap stabilized within a narrower range around −2.6 log points. Gap volatility fell from 0.42 to 0.21, a reduction of 50 percent. A variance ratio test rejects equality across regimes ($F = 4.42$, $p < 0.001$).

Domestic−International Fuel Price Gap

(a) Price gap level

(b) Rolling 12−month volatility



Notes: Shaded region indicates PPI period (October 2016 onward). Dashed vertical line marks PPI implementation.
Panel (a): Negative values indicate domestic prices below international benchmark.
Panel (b): Rolling standard deviation of monthly gap; dotted lines show regime means with arrows.

Figure 3: Domestic–International Fuel Price Gap

Notes: Panel (a) shows the log price gap ($\log p_t^D - \log p_t^B$) over the sample period. Negative values indicate domestic fuel prices below the international Brent benchmark. Panel (b) displays rolling 12-month standard deviation of the gap, with dotted horizontal lines indicating regime-specific means. The shaded region marks the PPI period (October 2016 onward).

Despite these differences in short-run dynamics, domestic and international prices are cointegrated in both regimes. Engle-Granger tests yield $\tau = -4.32$ (pre-PPI) and $\tau = -4.02$ (PPI), both significant at the 1 percent level. The main distinction is not the existence of a long-run equilibrium but the speed and predictability of adjustment. Deviations from the international benchmark are corrected faster and with more regular timing of price changes in the PPI period. These findings are consistent with the first testable prediction. PPI increased price pass-through and reduced gap volatility, satisfying the necessary condition for the transmission mechanism examined in Section 5.2.

5.2 Transmission Mechanisms

Table 2 reports estimates of the baseline exchange rate specification (14) for the pre-COVID sample. Under administered pricing, the coefficient on log Brent is small and statistically indistinguishable from zero ($\hat{\beta}_2 = 0.044$, 95% CI: $[-0.10, 0.19]$). The absence of a systematic contemporaneous relationship is consistent with limited pass-through from international to domestic prices. When the government sets fuel prices administratively, global oil-price movements carry no direct cost signal for domestic consumers or firms. After the introduction of PPI, the coefficient rises to 0.467 (95% CI: $[0.34, 0.59]$), and this difference is robust to HAC inference ($\hat{\beta}_3 = 0.423$, HAC 95% CI: $[0.15, 0.70]$). Under rule-based pricing, international oil prices transmit directly to domestic fuel costs, and higher fuel prices are associated with real depreciation through inflation and terms-of-trade channels.

Table 2: Fuel Price Pass-Through to Real Exchange Rate: Pre-COVID Sample

	(1) HC1	(2) HAC(12)
Panel A: Coefficients		
Log Brent price (p_t^{fuel})	0.044	0.044
	(0.074)	(0.121)
$p_t^{\text{fuel}} \times$ PPI	0.423^{***}	0.423^{***}
	(0.070)	(0.139)
PPI regime	-1.808^{***}	-1.808^{***}
	(0.349)	(0.557)
Panel B: Marginal Effects (Delta Method)		
Pre-PPI effect	0.044	0.044
	[−0.102, 0.189]	[−0.192, 0.280]
PPI effect	0.467^{***}	0.467^{***}
	[0.342, 0.593]	[0.213, 0.722]
Difference (PPI − Pre)	0.423^{***}	0.423^{**}
	[0.286, 0.561]	[0.152, 0.695]
Controls	Yes	Yes
Observations	204	204
R^2	0.889	0.889

Notes: Dependent variable: $q_t = -\log(\text{REER}_t/100)$; positive coefficients indicate depreciation. Sample: 2003:03–2020:02 (pre-COVID). Controls: interest rate differential, fuel volatility (with PPI interaction), terms of trade, lagged cupom cambial spread, VIX, CDS spread. Panel A: standard errors in parentheses. Panel B: 95% confidence intervals in brackets. Column (1): HC1 robust standard errors. Column (2): Newey-West HAC with 12 lags and VAR(1) prewhitening. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 3 reports estimates with the five-year sovereign CDS spread as the dependent variable. Under administered pricing, the fuel–CDS relationship runs in the opposite direction from the exchange rate. Higher oil prices are associated with lower sovereign risk, with an estimated slope of −288.5 basis points per log-point increase in Brent ($p < 0.01$) in the full-sample specification. This pattern is consistent with a commodity-windfall mechanism in which rising oil prices strengthen Petrobras's cash flow and improve the public sector's fiscal position. Under PPI, the windfall benefit attenuates substantially. In the full sample, the implied effect contracts to −135 basis points (a 53 percent reduction). In the pre-COVID subsample, where the PPI regime is cleanly identified, the effect reverses sign to +188 basis points. Higher fuel prices are now associated with higher sovereign risk—the opposite of the administered-pricing pattern.

Table 3: Sovereign Risk Response to Fuel Prices

	Full Sample		Pre-COVID	
	(1) CDS Simple	(2) CDS Full	(3) CDS Simple	(4) CDS Full
Log Brent (p_t^{fuel})	−242.5***	−288.5***	−206.8***	−315.6***
	(20.3)	(45.2)	(24.2)	(105.3)
PPI regime	−380.6**	−688.2***	−2305.5***	−2128.4***
	(191.1)	(151.0)	(302.8)	(300.1)
$p_t^{\text{fuel}} \times$ PPI	108.2**	153.8***	581.6***	503.2***
	(42.5)	(32.4)	(75.9)	(72.1)
$\sigma_t^{\text{fuel}} \times$ PPI		273.8***		
		(59.4)		
Marginal Effects (bp per log-point)				
Pre-PPI effect	−242.5	−288.5	−206.8	−315.6
PPI effect	−134.3	−134.7	374.8	187.6
Interest rate differential	Yes	Yes	Yes	Yes
Fuel volatility	Yes	Yes	Yes	Yes
Terms of trade	No	Yes	No	Yes
Cupom spread (lag)	No	Yes	No	Yes
VIX	Yes	Yes	Yes	Yes
Observations	243	243	204	204
R^2	0.773	0.843	0.811	0.862

Notes: Dependent variable is 5-year sovereign CDS spread in basis points. Columns (1)–(2) use the full sample (2003:03–2023:05); columns (3)–(4) use the pre-COVID sample (2003:03–2020:02). HC1 robust standard errors in parentheses. The marginal effect under PPI equals the sum of the fuel coefficient and the interaction term. In the pre-COVID sample, the sign of the PPI-era effect reverses: higher fuel prices are associated with *higher* CDS spreads under PPI, consistent with pass-through of commodity price risk to consumers rather than fiscal absorption. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

This sign reversal is consistent with the risk reallocation mechanism in Section 3. Under administered pricing, the government absorbed oil price risk on both sides. It captured the upside through Petrobras dividends while bearing the downside through implicit fuel subsidies, so higher oil prices improved the net fiscal position. Under PPI, oil-price risk is passed through to consumers, who share the gains but also bear the costs. Higher fuel prices then raise inflation, compress real incomes, and intensify political tensions, as illustrated by the 2018 truckers' strike triggered by diesel price increases under the PPI formula. The fiscal gains from commodity windfalls are smaller when a larger share of the adjustment burden falls on the private sector.

Appendix D provides firm-level corroboration of this channel using Petrobras equity data. Under administered pricing, Petrobras realized volatility moves strongly with Brent price volatility. Under PPI, this sensitivity disappears while co-movement with the broad equity market rises. The frequency of idiosyncratic return surprises falls by 44% under PPI, consistent with rule-based pricing eliminating the anticipation premium embedded in Petrobras equity risk.

5.3 Volatility Reduction

The increased contemporaneous pass-through documented in Section 5.2 does not imply that the exchange rate became more sensitive to oil shocks in terms of overall volatility. What changed is the channel through which oil prices matter. Before PPI, domestic fuel prices adjusted infrequently, so oil-price movements were less a direct cost shock and more a signal about the timing and scale of discretionary interventions. The anticipation of those interventions affected sovereign risk and funding conditions and, through the risk-premium term in equation (1), moved the exchange rate. With the introduction of PPI, domestic prices began tracking Brent more closely, and the informational content of oil-price fluctuations regarding future interventions disappeared. The removal of discretionary policy risk more than offsets the increase in market-driven pass-through, producing lower overall volatility.

Table 4: Volatility Reduction Under PPI: Pre-COVID Sample

	Pre-PPI (n=163)	PPI (n=41)	Change (%)	F-stat	p-value
Panel A: Risk Premium Volatility					
CDS spread (bp)	209.3	53.3	−74.6	15.44	<0.0001
Cupom cambial (pp)	1.90	0.63	−67.0	—	—
Panel B: Exchange Rate Volatility					
REER (log, σ_q)	0.196	0.071	−63.6	7.56	<0.0001
Nominal FX (annual, %)	16.2	14.5	−10.2	—	—
Panel C: Tail Risk (monthly, bp)					
VaR 95%	611	554	−9.4	—	—
VaR 99%	966	684	−29.2	—	—
Panel D: Crisis Probability					
P(q > 98th pctl)	3.07%	0.00%	−100	—	—

Notes: Pre-COVID sample (2003:03–2020:02). Panels A–B report standard deviations. F-statistics test $H_0 : \sigma^2_{\text{pre}} = \sigma^2_{\text{PPI}}$ against $H_1 : \sigma^2_{\text{pre}} > \sigma^2_{\text{PPI}}$. Panel C: VaR computed as negative of left-tail percentiles of monthly nominal FX returns (depreciation risk). Panel D: Probability of exceeding 98th percentile of pre-COVID distribution.

Table 4 documents this reduction for the pre-COVID sample. The standard deviation of CDS spreads falls from 209 basis points to 53 basis points, a reduction of 75 percent ($F = 15.44$, $p < 0.001$). Real exchange rate volatility declines from 0.196 to 0.071, a reduction of 64 percent

($F = 7.56$, $p < 0.001$). Cupom cambial volatility falls by 67 percent. Tail risk measures point in the same direction: the 95th percentile of monthly nominal FX depreciation falls from 611 to 554 basis points, and the probability of exceeding the 98th percentile of the pre-COVID REER distribution falls to zero under PPI.

5.4 Dynamic Responses

Figure 4 plots cumulative impulse responses from local projections for horizons $h = 0, \ldots, 12$ months. Table 5 reports coefficients at selected horizons, estimated with lag-augmented local projections and EHW standard errors following Montiel Olea and Plagborg-Møller (2021).

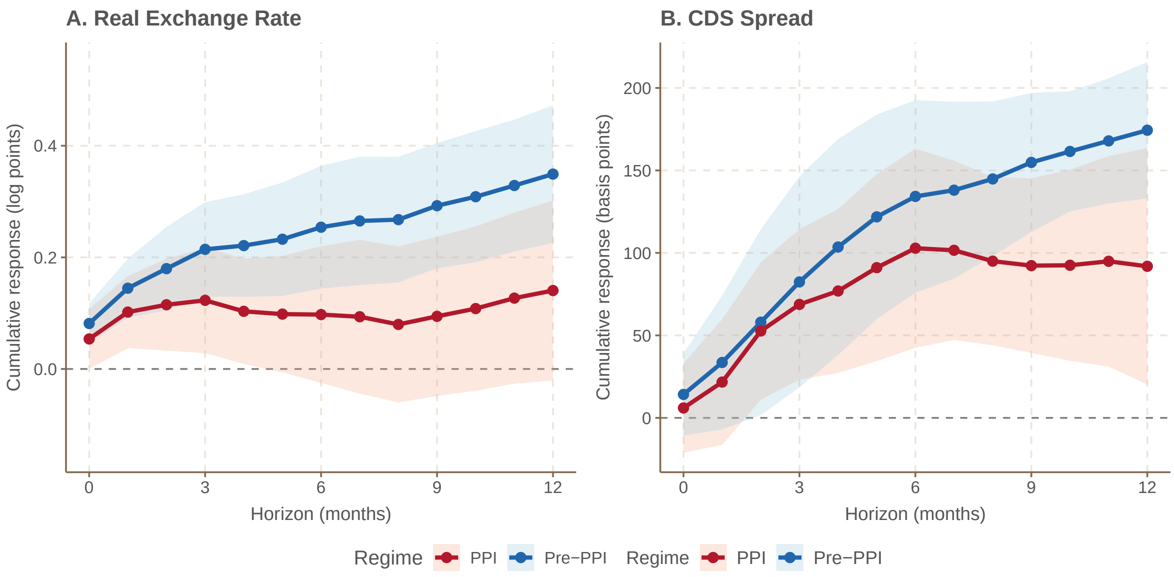


Figure 4: Dynamic Response of Exchange Rates and CDS Spreads to Fuel Price Shocks

Notes: Cumulative impulse response to a fuel price shock by pricing regime. Panel A shows the real exchange rate response (positive = depreciation); Panel B shows the CDS spread response. Coefficients correspond to a one-unit change in log fuel prices; for a 10% shock, multiply by 0.095. Shaded areas are 95% confidence intervals using Montiel Olea and Plagborg-Møller (2021) inference (lag-augmented local projections with Eicker-Huber-White standard errors). Sample: 2003:03–2023:05. Pre-PPI effects (blue) are large and significant at all horizons. PPI effects (red) are attenuated by 34–68% for REER and 17–47% for CDS.

In the pre-PPI administered-pricing regime, a fuel price innovation generates cumulative real depreciation that increases over the forecast horizon: 0.08 log points on impact, 0.25 at six months, and 0.35 at twelve months, all statistically significant. Under PPI, the cumulative response is smaller at horizons beyond impact, with estimates of 0.10 at six months (62% attenuation) and 0.14 at twelve months (60% attenuation). These coefficients remain positive but are statistically insignificant at medium horizons.

Table 5: Local Projections: Dynamic Response to Fuel Price Shocks

	Real Exchange Rate			CDS Spread (bp)		
Horizon	Pre-PPI	PPI	Atten.	Pre-PPI	PPI	Atten.
$h = 0$	0.082^{***}	0.054^{*}	34%	14	6	58%
	(0.018)	(0.027)		(13)	(14)	
$h = 3$	0.214^{***}	0.123^{**}	43%	82^{**}	69^{***}	17%
	(0.043)	(0.048)		(33)	(23)	
$h = 6$	0.254^{***}	0.097	62%	134^{***}	103^{***}	23%
	(0.056)	(0.062)		(30)	(31)	
$h = 9$	0.293^{***}	0.094	68%	155^{***}	92^{***}	40%
	(0.057)	(0.073)		(22)	(27)	
$h = 12$	0.349^{***}	0.141^{*}	60%	174^{***}	92^{**}	47%
	(0.063)	(0.082)		(21)	(37)	
Observations	234–241			234–241		

Notes: Local projection estimates following Montiel Olea and Plagborg-Møller (2021). Specifications include lag augmentation; inference uses Eicker-Huber-White heteroskedasticity-robust standard errors. Coefficients correspond to a one-unit change in $\log p^{\text{fuel}}$ (100% price increase); for a 10% shock, multiply by 0.095. "Atten." is the percent reduction in magnitude under PPI. REER controls: interest differential, fuel volatility (with PPI interaction), terms of trade, cupom spread, VIX, CDS, lagged REER change. CDS controls: interest differential, fuel volatility, VIX, lagged CDS change. Sample: 2003:03–2023:05. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

The CDS responses are attenuated under PPI. Under administered pricing, fuel prices generate CDS increases of 134 bp at six months and 174 bp at twelve months, both highly significant. Under PPI, the responses are attenuated by 23% at six months and 47% at twelve months. At extended horizons ($h \geq 18$), the PPI-era CDS point estimates turn negative. This pattern is consistent with a balance-sheet interpretation that once the short-run pass-through and inflation channels fade, higher fuel prices under PPI improve Petrobras's cash flow and reduce perceived contingent fiscal liabilities, lowering sovereign risk.

At longer horizons, the picture changes further. Appendix A extends the projections to 24 months. REER responses across regimes converge by $h = 18$, in line with the cointegration evidence, suggesting that the reform mainly affects persistence rather than the long-run equilibrium. Sovereign risk responses, by contrast, behave differently across regimes. Under PPI, the CDS coefficients turn negative from $h \geq 18$, consistent with a regime in which higher fuel prices improve Petrobras's cash flow and reduce perceived fiscal contingent liabilities. TThe pre-COVID estimates reinforce this contrast despite the shorter PPI window ($n_{\text{PPI}} = 41$). At $h = 12$, the CDS response is +162 bp in the pre-PPI regime and −312 bp under PPI. These dynamics support a dual-channel interpretation. Short-horizon responses capture the pass-through channel activated under PPI. While medium-horizon effects reflect the commodity-fiscal channel that weakens under PPI. The overall impact depends on the relative strength of these mechanisms at each horizon.

Appendix A extends the projections to $h = 24$ months. REER responses across regimes converge by $h = 18$, consistent with the cointegrating relationship in Section **??**. CDS coefficients under

PPI turn negative from $h \geq 18$, with the pre-COVID estimates reaching -312 basis points at $h = 12$ and -452 basis points at $h = 18$.

5.5 Identification Strategy

Our difference-in-differences (DiD) design exploits the discrete policy change in October 2016. We assess the plausibility of a causal interpretation using structural break tests, placebo analyzes, pre-trend diagnostics, and commodity-channel tests. Table 6 reports tests for parameter instability in the fuel price–exchange rate relationship. The Chow test rejects stability at the PPI implementation date ($F = 33.84$, $p < 0.0001$). A supremum F-test, which searches over break dates without imposing a known threshold, yields $\sup F = 273.12$ ($p < 0.0001$) with the estimated break falling in September 2016, immediately before the formal introduction of PPI. These tests indicate a dated break in the fuel–exchange-rate mapping that coincides with the PPI regime change.

Table 6: Structural Break Tests at PPI Implementation

Test	Statistic	p-value
Chow test (October 2016)	$F = 33.84$	< 0.0001
Supremum F test (unknown break)	$\sup F = 273.12$	< 0.0001
Identified break date	September 2016	

Notes: Tests for structural break in the fuel price–exchange rate relationship. The Chow test evaluates parameter stability at the known PPI implementation date. The supremum F test searches over all possible break dates in the interior 70% of the sample. Both tests reject stability, with the identified break coinciding with PPI implementation.

5.5.1 Placebo Test.

To rule out spurious regime effects, we assign a fictitious "fake PPI" period from October 2013 to May 2015, chosen to match the duration and oil market volatility of the actual PPI window. Column (3) of Table 7 shows that the placebo interaction is economically negligible and statistically insignificant ($\hat{\beta} = -0.004$, $p = 0.955$). Alternative placebo windows (not reported) deliver similarly small and insignificant effects. The absence of placebo breaks strengthens the interpretation that the estimated regime shift is tied to the actual PPI reform.

5.5.2 Parallel Trends.

The DiD interpretation requires that, absent PPI, the fuel price–exchange rate relationship would have remained stable. We evaluate this by estimating a time-varying coefficient during the pre-PPI period, interacting fuel prices with a linear time trend. The resulting estimates are summarized in Table 8.

Table 7: Robustness Tests: Alternative Specifications

	Baseline (Brent) (1)	Domestic (Gasoline) (2)	Placebo PPI (3)	Pre-Trend Test (4)
Log fuel price	-0.461^{***}	-0.100^{**}	-0.510^{***}	0.029
	(0.060)	(0.045)	(0.058)	(0.083)
PPI regime	-1.027^{***}	-1.166^{***}		
	(0.243)	(0.138)		
Fuel × PPI	0.252^{***}	0.879^{***}		
	(0.053)	(0.096)		
Fake PPI			0.042	
			(0.322)	
Fuel × Fake PPI			−0.004	
			(0.070)	
Time trend				-0.040^{**}
				(0.017)
Fuel × Trend				0.008^{*}
				(0.004)
Controls	Yes	Yes	Yes	Yes
Sample	2003–2023	2003–2023	2003–2023	Pre-PPI
Observations	243	243	243	163
R^2	0.824	0.858	0.797	0.921

Notes: Dependent variable: $q_t = -\log(\text{REER}_t/100)$ (positive = depreciation). Column (1): baseline with Brent. Column (2): domestic gasoline prices. Column (3): placebo PPI (Oct 2013–May 2015). Column (4): pre-trend test on pre-PPI period. HC1 standard errors in parentheses. Controls: interest differential, fuel volatility, terms of trade, cupom spread, VIX, CDS spread. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 8: Parallel Trends Sensitivity Analysis

Specification	$\hat{\beta}_1$	SE	p-value	n
Full Pre-Period (2003–2016)	0.008	0.004	0.051	163
Short Window (2014–2016)	−0.085	0.056	0.145	33
With NetImporter Control	0.007	0.004	0.113	163

Notes: Coefficient on $p_t^{\text{fuel}} \times t$ from pre-trend regression. HC1 standard errors. The positive trend in the full pre-period would bias *against* finding a PPI effect, making our estimates conservative. Restricting to 2014–2016 or controlling for net trade position eliminates significance.

Using the full pre-PPI period (2003–2016), we find a marginally significant positive trend ($\hat{\beta}_1 = 0.008$, $p = 0.051$). Three considerations mitigate concerns about this trend. First, the sign of the trend works against our main result. A positive pre-trend implies that, absent reform, fuel prices would have become more strongly associated with depreciation over time. Extrapolating that pattern forward, one would expect the post-2016 fuel–exchange-rate relationship to strengthen rather than weaken. Our finding that fuel-driven depreciation pressures are attenuated under PPI therefore cannot be explained solely by the pre-existing trend; if anything, under a linear extrapolation of the trend, the bias pushes our estimated attenuation toward zero.

Second, the trend disappears in a local window around the policy change. Restricting the pre-period to 2014–2016, the coefficient reverses sign and becomes statistically insignificant ($\hat{\beta}_1 = -0.085$, $p = 0.145$). This pattern suggests that the full-sample trend reflects slow-moving structural changes in Brazil's oil trade position rather than a violation of parallel trends in the neighborhood of the regime shift. Third, controlling for Brazil's net oil trade position—transitioning from net importer to net exporter over the sample—renders the trend insignificant ($p = 0.113$). This supports the interpretation that the apparent pre-trend is largely driven by the oil-sector transition, not by unmodeled dynamics correlated with the timing of PPI.

5.5.3 The 2015 Adjustment Episode

A potential concern is that any fuel price adjustment—not specifically rule-based pricing—might reduce exchange rate volatility. The 2015 episode provides a natural counterfactual. In early 2015, after international oil prices fell from above \$100 per barrel to below \$50, Brazil's domestic fuel prices moved in the opposite direction (Figure 5). This pattern reflects the discretionary nature of administered pricing. With international prices declining, the government raised domestic fuel prices to address Petrobras's financial distress—a response driven by fiscal conditions rather than market fundamentals.

Figure 5 illustrates the regime shift in comovement. In the pre-PPI period, Brent and domestic prices display weak correlation with prolonged episodes of divergence; in the post-PPI period, domestic prices closely track international benchmarks despite short-run fluctuations. This pattern complements the pass-through estimates in Table 1.

Figure 5: Domestic Fuel Prices vs. International Oil (Brent), 2011–2018

Notes: Solid line shows Brent crude oil prices (USD/barrel, left axis). Dashed line shows Brazil's domestic gasoline prices (BRL/liter, right axis). Both series normalized to 100 in January 2011. The shaded region indicates the PPI period (October 2016 onward). During early 2015, international oil prices declined sharply while domestic prices increased, reflecting Petrobras's fiscal adjustment under administrative pricing. Post-October 2016, the series move in tandem, consistent with PPI's commitment to continuous pass-through from international benchmarks.

Table 9: Volatility During 2015 Adjustment Episode vs. PPI

	2013–2014 (Stable)	2015–2016 (Adjustment)	PPI (Pre-COVID)	F-test
Panel A: Volatility Measures				
REER volatility (σ_q)	0.046	0.092	0.071	
Change vs. 2013–14	—	+100%	+54%	
Change vs. 2015–16	—	—	−23%	
CDS spread (mean, bp)	163	339	192	
Change vs. 2013–14	—	+108%	+18%	
Change vs. 2015–16	—	—	−43%	
FX volatility (annual, %)	12.3	24.2	14.5	
Change vs. 2013–14	—	+97%	+18%	
Change vs. 2015–16	—	—	−40%	
Panel B: Variance Ratio Tests				
H_0: $\sigma^2_{15-16} = \sigma^2_{13-14}$		$F = 3.99$, $p = 0.0009$		Reject
H_0: $\sigma^2_{15-16} = \sigma^2_{\text{PPI}}$		$F = 1.68$, $p = 0.081$		Marginal
Observations	24	21	41	

Notes: Volatility measured as standard deviation of monthly observations within each period. The 2015–2016 period includes discrete fuel price adjustments under administered pricing following the Rousseff administration's fiscal consolidation. Despite these adjustments, volatility *doubled* relative to 2013–2014 ($F = 3.99$, $p < 0.001$). The PPI period shows volatility reduction relative to the adjustment episode, confirming that rule-based pricing—not price adjustments per se—drives stabilization.

If discrete, administratively determined price increases were sufficient to stabilize the exchange rate and reduce sovereign risk, volatility reductions should be observable during 2015–2016 when such adjustments occurred. Table 9 reports the opposite: exchange rate volatility doubled during 2015–2016 relative to 2013–2014 (σ_q: $0.046 \rightarrow 0.092$, $F = 3.99$, $p < 0.001$), and CDS spreads more than doubled (163 to 339 bp). The PPI period exhibits substantial reductions relative to the adjustment episode—REER volatility fell 23%, CDS spreads fell 43%, and FX volatility fell 40%—consistent with the view that predictability of the pricing rule, not the price adjustment itself, drives stabilization.

5.5.4 Commodity Channel Specificity.

A remaining concern is that the October 2016 break might reflect broader macroeconomic stabilization, rather than a change specific to fuel pricing. We address this with a "horse-race" specification that allows differential PPI effects for fuel and non-fuel commodity prices:

$$q_t = \alpha + \gamma_F(p_t^{\text{fuel}} \times \text{PPI}_t) + \gamma_N(p_t^{\text{nonfuel}} \times \text{PPI}_t) + \Gamma' X_t + \varepsilon_t \tag{18}$$

Under the null that PPI affected all commodity transmission equally, $\gamma_F = \gamma_N$.

Three patterns point to fuel-specific transmission (Table 10). First, in the horse-race specification, the fuel interaction coefficient rises modestly from 0.611 (univariate) to 0.669 when non-fuel commodities are added, whereas the non-fuel interaction declines from 0.613 to 0.235

Table 10: Commodity Channel Test: Fuel vs. Non-Fuel

	Non-Fuel Only (1)	Fuel Only (2)	Horse Race (3)
Log(Gasoline)		−0.085	−0.072
		(0.057)	(0.045)
Gasoline × PPI		0.611^{***}	0.669^{***}
		(0.088)	(0.123)
Log(Non-fuel)	-0.301^{***}		-0.298^{***}
	(0.043)		(0.036)
Non-fuel × PPI	0.613^{***}		0.235^{**}
	(0.052)		(0.089)
PPI Regime	-2.948^{***}	-0.807^{***}	-2.050^{***}
	(0.259)	(0.112)	(0.327)
Controls	Yes	Yes	Yes
Observations	243	243	243
R^2	0.839	0.825	0.867
Differential Effect Test (Column 3):			
Fuel − Non-fuel	0.435^{**} (SE = 0.196)		
95% CI	[0.050, 0.819]		

Notes: Dependent variable: $q_t = -\log(\text{REER}_t/100)$. HC1 standard errors in parentheses. Column (3) includes both commodity types with PPI interactions. The differential effect test confirms fuel transmission changed significantly more than non-fuel under PPI. Controls: interest differential, fuel volatility, cupom spread, VIX, CDS spread. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

(a reduction of about 62%). This suggests that part of the apparent non-fuel effect in the univariate specification reflects its correlation with fuel prices, which is absorbed once fuel is included. Second, the differential effect is statistically meaningful: testing $H_0\colon \gamma_F = \gamma_N$ yields $\hat{\gamma}_F - \hat{\gamma}_N = 0.435$ with a 95% confidence interval $[0.050, 0.819]$, so the null of equal effects is rejected. Third, the economic magnitudes favor fuel, as the fuel effect (0.669) is nearly three times larger than the non-fuel effect (0.235); a 10% fuel price increase under PPI is associated with roughly 6.7% real depreciation, compared with about 2.4% for an equivalent non-fuel price increase.

The residual non-fuel effect (0.235) may reflect concurrent macroeconomic stabilization or correlated movements in commodity prices driven by common global demand shocks and financial conditions (Byrne et al., 2013). Such a pattern is compatible with the identification strategy, as structural break tests locate a change at the PPI introduction, placebo exercises show no comparable shift in non-policy windows, and the differential estimates indicate a quantitatively and statistically stronger effect for fuel. Overall, the evidence supports a causal interpretation in which PPI specifically altered fuel-price pass-through to the exchange rate.

5.6 The 2023 Reversal

In May 2023, Petrobras formally abandoned PPI and returned to a hybrid pricing framework with greater managerial discretion. This second institutional break provides an additional identification test. If the stabilization documented in Sections 5.2–5.3 reflects the fuel-pricing regime rather than concurrent fiscal developments, abandoning PPI should reverse the transmission mechanisms through which oil shocks propagate to the exchange rate and sovereign risk. The institutional timeline aids this test because PPI and the fiscal expenditure ceiling, though introduced nearly simultaneously in late 2016, were removed at different dates—PPI in May 2023 and the expenditure ceiling in August 2023—creating a window in which the fuel-pricing regime changed while the fiscal framework remained in place.[3] We define three regimes—Pre-PPI (before October 2016), PPI (October 2016–May 2023), and Post-PPI (June 2023 onward)—and extend the baseline specifications to include a Post-PPI indicator and its interactions with fuel prices.[4]

Table 11 reports pass-through and transmission statistics across the three regimes. The transmission mechanisms reversed once PPI was abandoned. The pass-through elasticity from Brent to domestic fuel prices, which rose from 0.14 to 0.61 with PPI, collapsed to −0.18 after its abandonment ($F = 89.3$, $p < 0.001$ for equality between PPI and Post-PPI elasticities). The negative sign indicates that domestic prices now move against international benchmarks when Brent rises, consistent with the hybrid regime actively smoothing imported price shocks. The correlation between domestic and international fuel prices, which had risen from 0.34 to 0.77 under PPI, fell to −0.45, indicating that the pricing decoupling characteristic of administered pricing re-emerged.

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[3] The expenditure ceiling (*teto de gastos*), enacted as Constitutional Amendment 95 in December 2016, limited the real growth of federal primary expenditures for twenty years. It was replaced by the *arcabouço fiscal* in August 2023, three months after PPI was abandoned.

[4] Unconditional volatility continued to decline after PPI's abandonment, reflecting the benign global environment of 2023–2026 rather than the pricing regime. The relevant test concerns transmission coefficients, which are identified from the covariation between oil-price movements and outcomes within each regime rather than from unconditional moments.

Table 11: Three-Regime Comparison: Pass-Through and Transmission

	Pre-PPI (2003:03–2016:09)	PPI (2016:10–2023:05)	Post-PPI (2023:06–2026:01)
Panel A: Price alignment			
Correlation (domestic–Brent)	0.338	0.768	−0.453
Pass-through elasticity ($\hat{\kappa}$)	0.135	0.613	−0.180
Panel B: Transmission coefficients			
Fuel → REER	-0.253^{***}	0.101^{*}	-0.329^{***}
Fuel → CDS (bp)	-45.5^{**}	−8.5	$+71.3^{**}$
Observations	164	80	27

Notes: Panel A reports the correlation between log domestic fuel prices and log Brent, and the pass-through elasticity from $p_t^D = \kappa_0 + \kappa\, p_t^B + u_t$ estimated separately by regime. Panel B reports regime-specific marginal effects from the three-regime specification in equation (19), computed via the delta method with HC1 standard errors. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

The exchange-rate and sovereign risk responses follow the same pattern. We extend the baseline specification to include Post-PPI interactions:

$$q_t = \alpha + \beta_1 r_t^{\text{diff}} + \beta_2 p_t^{\text{fuel}} + \beta_3 (p_t^{\text{fuel}} \times \text{PPI}_t) + \beta_4 (p_t^{\text{fuel}} \times \text{Post}_t) + \mathbf{\Gamma}'\mathbf{X}_t + \varepsilon_t. \tag{19}$$

The fuel–REER coefficient under Post-PPI is −0.329 (Panel B of Table 11), statistically indistinguishable from the Pre-PPI value of −0.253 ($F = 0.62$, $p = 0.43$) and rejected against the PPI value ($F = 13.7$, $p < 0.001$). The fuel–exchange-rate relationship has reverted to its pre-reform structure, so fuel prices and the real exchange rate move in the same direction, consistent with the commodity-currency channel operating without the pass-through reversal that PPI introduced.

The CDS–fuel coefficient shifts from −45.5 basis points pre-PPI to −8.5 under PPI and reverses sign to +71.3 in the Post-PPI period ($F = 3.23$, $p = 0.074$ for equality between PPI and Post-PPI). Higher oil prices now raise sovereign risk, consistent with the hybrid regime reintroducing fiscal uncertainty: when pricing decisions are discretionary, rising oil prices signal potential pressure on Petrobras's pricing policy and the associated fiscal contingent liabilities, rather than a windfall absorbed through a rule-based formula.

The reversal analysis provides evidence against a fiscal-credibility interpretation of the 2016 stabilization. Pass-through collapsed and turned negative. The fuel–exchange-rate relationship returned to its pre-reform structure ($p = 0.43$ for equality with Pre-PPI; $p < 0.001$ for equality with PPI). The CDS–fuel channel reversed sign. All of this occurred while the fiscal framework remained in place. The evidence is mostly explained by the fuel-pricing regime itself, operating through the transmission channels identified in Section 3.

6 Conclusion

This paper studies how fuel-pricing regimes shape exchange-rate and sovereign-risk dynamics in a commodity-exporting emerging market. Exploiting Brazil's October 2016 transition from administered pricing to import-parity pricing (PPI) and the subsequent reversal in May 2023, we document a fundamental change in the mechanism through which oil shocks reach the exchange rate and sovereign risk. Under administered pricing, higher oil prices reduced sovereign spreads through a commodity-windfall channel, improving Petrobras's cash flow and lowering perceived fiscal contingent liabilities. Under PPI, the same shock widened sovereign spreads, reflecting a reallocation of oil-price risk from the sovereign balance sheet to consumers and firms. This reallocation compressed the fiscal-uncertainty amplification channel and produced large reductions in aggregate volatility: in the pre-COVID sample, REER volatility fell by 64% and sovereign CDS spread volatility fell by 75%, despite PPI increasing the pass-through elasticity of domestic fuel prices to the Brent benchmark from 0.10 to 0.46.

Our results are consistent with stabilization operating through credibility and expectations. Under administered pricing, discretionary and unpredictable adjustments created a policy uncertainty channel linking fuel prices to sovereign risk premia and exchange-rate movements. Rule-based adjustment under PPI reduced uncertainty about future interventions and weakened the sovereign-risk amplification mechanism, even as the exchange rate became more responsive to global oil fundamentals. The May 2023 reversal confirms this interpretation. Once PPI was abandoned, the pass-through elasticity collapsed, and the transmission coefficients returned to their pre-reform structure, while the fiscal expenditure framework remained in place, isolating the fuel-pricing regime as the operative channel. The May 2018 truckers' strike, which triggered a temporary suspension of daily price adjustments, illustrates that political-economy constraints remain binding even under well-designed rules. This episode nonetheless illustrates the distinction between rule-based pricing and episodic discretionary intervention.

As countries navigate energy transitions, volatile commodity markets, and mounting fiscal pressures, understanding how pricing regime design shapes macroeconomic outcomes becomes relevant for both policymakers and researchers. Our findings speak directly to ongoing fuel pricing reform debates in emerging markets. Several countries have attempted liberalization programs similar to Brazil's PPI, and many have struggled to maintain commitment during adverse shocks. Indonesia introduced automatic price adjustment rules in 2014 and applied them during the 2015–2016 oil price decline, but suspended adjustments when prices rebounded in early 2017 (Abriningrum et al., 2024). Mexico shifted to market-based pricing on January 1, 2017, then resorted to discretionary subsidies in March 2022 following the surge in international prices associated with the Russia–Ukraine conflict (Mariscal and Miranda, 2024). Colombia has moved toward subsidy removal under fiscal pressure from its stabilization fund, whose deficit reached 1.1% of GDP in 2018, alongside concerns about declining petroleum production (International Monetary Fund, 2019). These episodes underscore the political-economy challenge. Yet, even when efficiency and fiscal gains are substantial, removing fossil fuel subsidies remains difficult in developing economies, and governments frequently return to discretionary interventions during adverse shocks (Montes de Oca Leon et al.).

These findings open several avenues for future research. One is to identify institutional complementarities that support the durability of market-based pricing, including the interaction of import-parity rules with inflation targeting frameworks and foreign exchange intervention capacity. A second is to quantify the distributional consequences of higher pass-through and their implications for political sustainability, since fuel price increases impose heterogeneous burdens across households and sectors. A third is to evaluate hybrid regimes, such as transparent price bands or smoothing rules, that may preserve credibility benefits while providing limited cushioning during extreme shocks. Overall, our evidence on the macroeconomic effects of state-owned enterprise pricing rules contributes to the literature on rules versus discretion in emerging-market policy. The finding that institutional commitment can deliver substantial macroeconomic stabilization, without recourse to reserve management, capital controls, or large countercyclical fiscal programs, underscores the central role of credibility mechanisms in commodity-dependent economies navigating volatile global markets.

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A Additional Local Projection Results

This appendix reports local projection results at extended horizons ($h = 18, 24$) and on the pre-COVID sample (2003:03–2020:02). These results complement the main-text findings by examining dynamics beyond the baseline $h \leq 12$ window and by isolating the period during which the PPI regime is defined.

This appendix reports additional local projection results: (i) extended horizons ($h = 18, 24$) for the full sample, and (ii) estimates on the pre-COVID sample (2003-2020:02), which restricts to the cleanly defined PPI regime but yields noisier estimates due to the shorter treatment window ($n_{\text{PPI}} = 41$).

Table 12 and Figure 6 report results at horizons up to 24 months. For the real exchange rate, the pre-PPI and PPI coefficients converge at $h = 18$ (0.419 vs. 0.396, both $p < 0.01$), and by $h = 24$ the PPI coefficient exceeds the pre-PPI coefficient (0.559 vs. 0.285). This convergence is consistent with the cointegrating relationship documented in Section **??**: PPI attenuates short-run depreciation via reduced uncertainty while leaving the long-run commodity-currency equilibrium intact.

Table 12: Local Projections: Extended Horizons (Full Sample)

	Real Exchange Rate		CDS Spread (bp)	
Horizon	Pre-PPI	PPI	Pre-PPI	PPI
$h = 0$	0.082^{***}	0.054^{*}	14	6
$h = 6$	0.254^{***}	0.097	134^{***}	103^{***}
$h = 12$	0.349^{***}	0.141^{*}	174^{***}	92^{**}
$h = 18$	0.419^{***}	0.396^{***}	222^{***}	-21
$h = 24$	0.285^{***}	0.559^{***}	255^{***}	-14

Notes: Local projection estimates at extended horizons. REER coefficients converge across regimes at $h = 18$; by $h = 24$, the PPI coefficient exceeds pre-PPI, consistent with stronger long-run commodity-currency dynamics once fiscal uncertainty is removed. The decline in the pre-PPI coefficient at $h = 24$ reflects mean reversion and reduced precision at extended horizons. CDS coefficients under PPI turn negative at $h \geq 18$, reflecting the fiscal benefit of higher fuel prices for Petrobras's balance sheet. Inference follows Montiel Olea and Plagborg-Møller (2021). Sample: 2003:03–2023:05. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

For CDS spreads, the pre-PPI coefficient continues to rise at extended horizons (222 bp at $h = 18$, 255 bp at $h = 24$), while the PPI coefficient turns negative (-21 bp and -14 bp). The sign reversal is consistent with the fiscal channel mechanism outlined in Section 3. Under administered pricing, increases in fuel prices signal future subsidy costs, expanding the pricing wedge w_t. Under PPI, the same price increases translate into higher Petrobras revenues, thereby improving the company's balance sheet and lowering implicit sovereign liabilities.

Table 13 and Figure 7 report estimates on the pre-COVID sample (2003:03–2020:02), which restricts the PPI regime to its defined phase but reduces statistical power ($n_{\text{PPI}} = 41$).

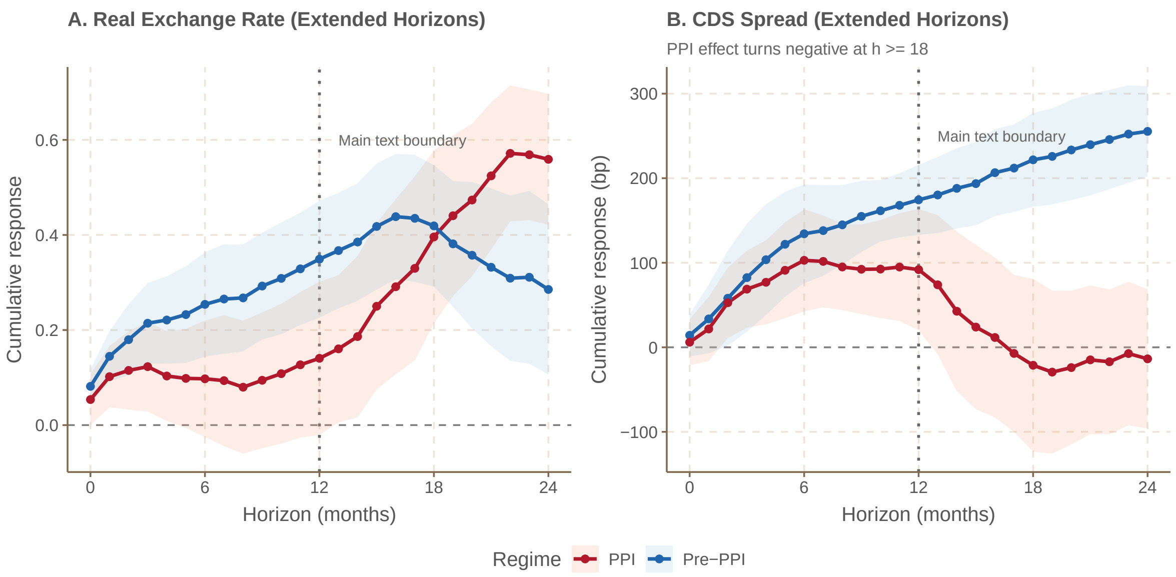

Figure 6: Local Projections: Extended Horizons

Notes: Cumulative impulse response at horizons $h = 0, \ldots, 24$ months. Vertical dotted line marks $h = 12$, the boundary for main-text results. Panel A: At extended horizons, REER coefficients converge across regimes, consistent with the cointegrating relationship. Panel B: CDS coefficients under PPI turn negative at $h \geq 18$, reflecting the fiscal benefit of higher fuel prices for Petrobras's balance sheet. Inference follows Montiel Olea and Plagborg-Møller (2021). Sample: 2003:03–2023:05.

Table 13: Local Projections: Pre-COVID Sample (2003–2020:02)

	Real Exchange Rate		CDS Spread (bp)	
Horizon	Pre-PPI	PPI	Pre-PPI	PPI
$h = 0$	0.081^{***}	0.003	16	7
$h = 6$	0.072	−0.003	148^{***}	0
$h = 12$	0.062	-0.198^{*}	162^{***}	-312^{***}
$h = 18$	0.084	-0.164^{**}	203^{***}	-452^{***}
Pre-PPI obs.	163		163	
PPI obs.	41		41	

Notes: Local projection estimates on the pre-COVID sample, which restricts the PPI regime to October 2016–February 2020. REER coefficients under pre-PPI are positive but statistically insignificant at $h \geq 6$, reflecting reduced power with fewer observations. REER coefficients under PPI turn negative (appreciation) by $h = 12$, consistent with faster convergence to long-run equilibrium. CDS coefficients show a contrast. Pre-PPI effects are large and positive (148–203 bp, all $p < 0.01$); PPI effects turn strongly negative (−312 bp at $h = 12$, −452 bp at $h = 18$, both $p < 0.01$). A 10% fuel price shock implies CDS reductions of approximately 30–43 bp under PPI at medium horizons—substantial fiscal benefits from eliminating subsidy commitments. Inference follows Montiel Olea and Plagborg-Møller (2021). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

For the real exchange rate, the pre-PPI coefficient is positive and significant on impact (0.081, $p < 0.01$) but becomes imprecisely estimated at longer horizons. The PPI coefficient turns negative by $h = 12$, indicating appreciation rather than depreciation—consistent with faster

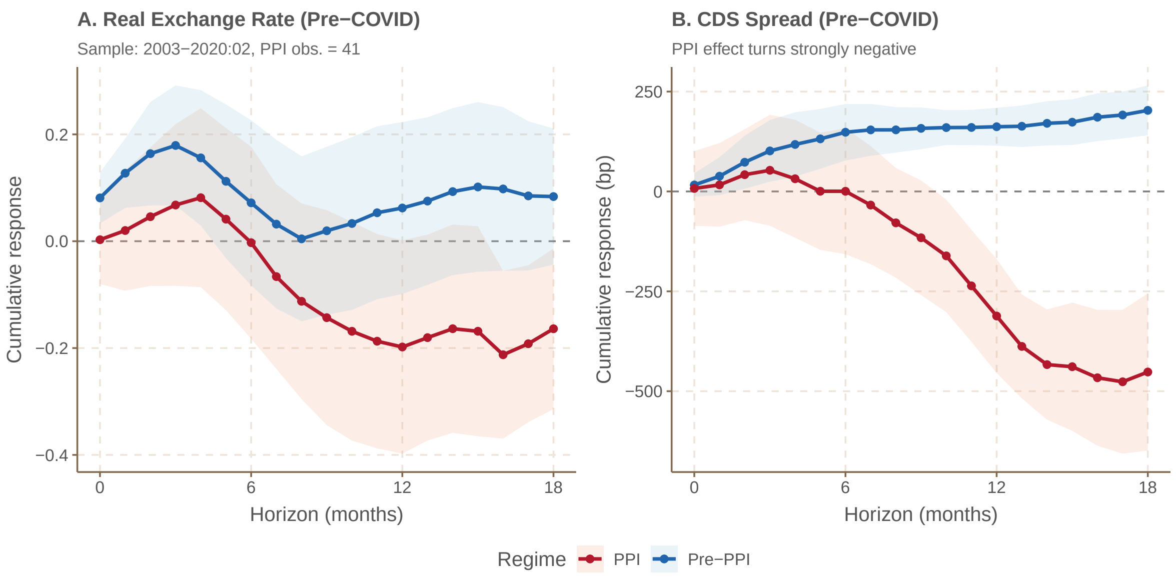

Figure 7: Local Projections: Pre-COVID Sample

Notes: Local projections estimated on the pre-COVID sample (2003:03–2020:02), which restricts the PPI regime to its cleanly defined phase (October 2016–February 2020, $n_{\mathrm{PPI}} = 41$). Panel A: REER estimates are noisier than the full sample, with PPI effects turning negative (appreciation) at medium horizons. Panel B: CDS estimates closely mirror the full-sample pattern—pre-PPI effects are positive and significant; PPI effects turn strongly negative, confirming the fiscal channel interpretation. The faster sign reversal relative to the full sample is consistent with the cointegration framework. Inference follows **?**.

convergence to long-run equilibrium, though these estimates should be interpreted cautiously given their imprecision. For CDS spreads, the pre-COVID sample yields results that strongly confirm the fiscal channel. Pre-PPI coefficients are large and significant throughout: 148 bp at $h = 6$, 162 bp at $h = 12$, and 203 bp at $h = 18$ (all $p < 0.01$). PPI coefficients show contrasting figures, ranging from zero at $h = 6$, then turning negative at medium horizons (-312 bp at $h = 12$, -452 bp at $h = 18$, both $p < 0.01$). When scaled to a 10% fuel price shock, these estimates imply CDS increases of 14–19 basis points at medium horizons under pre-PPI compared to CDS decreases of 30–43 basis points under PPI. The shift from positive to large negative effects provides evidence that PPI not only eliminated but also reversed the fiscal stress channel.

Figure 8 compares confidence intervals under HAC standard errors (Andrews, 1991) versus the lag-augmented approach of Montiel Olea and Plagborg-Møller (2021). The lag-augmented method yields tighter confidence intervals (approximately 50% smaller at $h \geq 6$) by absorbing serial correlation directly through lag inclusion rather than kernel-based variance estimation. Point estimates are similar across methods; qualitative conclusions are unchanged. We report HAC inference in the main text as the more conservative approach.

The extended-horizon and pre-COVID estimates broadly reinforce the main-text findings. Under the pre-PPI regime, administered fuel pricing transmitted price increases to higher sovereign risk through the wedge mechanism. Under PPI, in contrast, CDS responses are muted at short horizons and turn negative at medium to long horizons as the fiscal advantages of market-based pricing prevail. For the real exchange rate, both samples indicate convergence at extended horizons, consistent with cointegration. Causal identification builds on the static regressions and structural break tests presented in the main text, while these dynamic results provide complementary evidence on the persistence and sign of regime-dependent transmission.

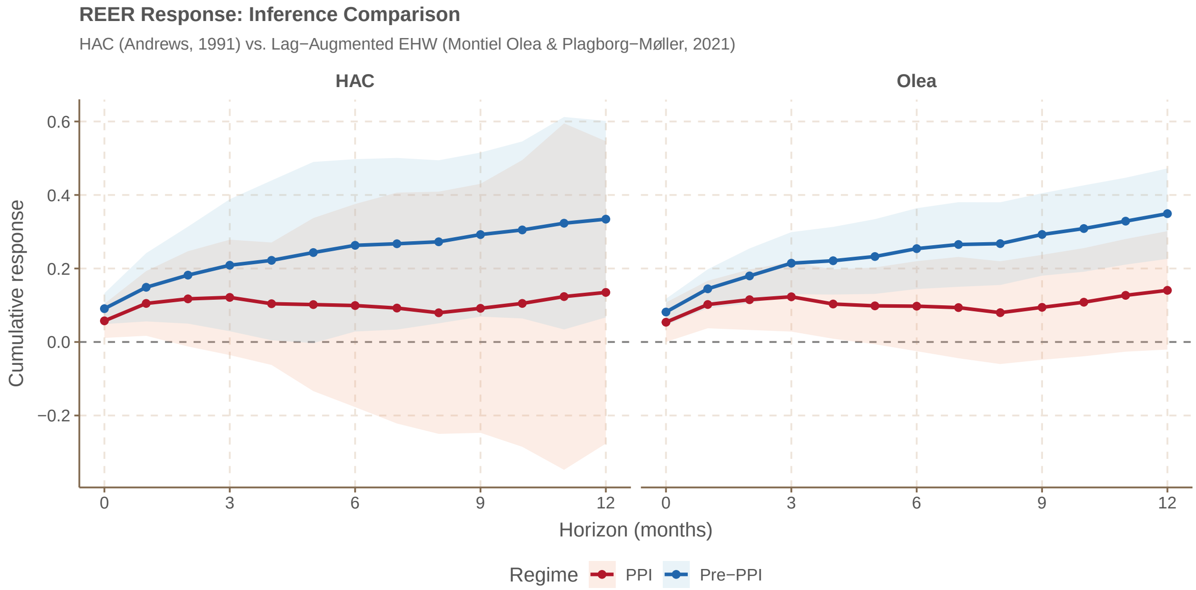

Figure 8: Local Projections: Inference Comparison

Notes: Comparison of confidence intervals under alternative inference procedures for the REER response. Left panel: HAC standard errors using Quadratic Spectral kernel with Andrews (1991) data-driven bandwidth. Right panel: Lag-augmented local projections with Eicker-Huber-White standard errors following Montiel Olea and Plagborg-Møller (2021). The lag-augmented approach yields tighter confidence intervals (approximately 50% smaller at $h \geq 6$) by absorbing serial correlation in the regression. Point estimates are similar across methods; qualitative conclusions are unchanged.

B Instrumental Variables and Reduced-Form Evidence

This appendix reports instrumental variable diagnostics and reduced-form evidence using the oil supply news shocks of Känzig (2021) as external corroboration of the institutional mechanism identified in the main text. The Wu-Hausman test does not reject OLS exogeneity ($p = 0.61$), suggesting that reverse causality does not affect the baseline estimates, though this result should be interpreted cautiously given the weak first stage for p_t^{fuel} under administered pricing.[5]

Table 14 reports first-stage diagnostics for the endogenous regressors p_t^{fuel} and $p_t^{\text{fuel}} \times \text{PPI}_t$, instrumented with the oil supply news shock and its interaction with PPI_t, with PPI_t entering as an exogenous regime indicator. The first stage is weak for p_t^{fuel} ($F = 0.59$) and strong for the interaction term ($F = 42.11$, $p < 0.001$). This asymmetry is consistent with the institutional mechanism. Under administered pricing, global oil supply news had no direct route to domestic fuel costs, so the instrument is appropriately weak in that regime; under PPI, supply news transmits through the import-parity formula. The asymmetry therefore corroborates the mechanism documented in Section 5.1 rather than representing a design limitation. The exclusion restriction does not hold for the structural causal effect of domestic fuel prices on q_t, since oil supply news affects the exchange rate through terms-of-trade and export-revenue channels independently of domestic fuel pricing. The IV diagnostics should therefore be read as corroborating the mechanism rather than as a source of causal identification.

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[5] We normalize the sign of the Känzig (2021) series so that a positive shock corresponds to news of higher future oil supply and thus lower oil prices.

Table 14: Instrumental Variables Diagnostics

	First-Stage F		p-value	
Endogenous Variable	HC1	HAC(12)	HC1	HAC(12)
p_t^{fuel}	0.59	0.59	0.621	0.621
$p_t^{\text{fuel}} \times \text{PPI}_t$	42.11	42.11	<0.001	<0.001
Specification Tests				
Wu-Hausman	$F = 0.493$		$p = 0.611$	
Anderson-Rubin	$F = 0.767$		$p = 0.514$	
Anderson-Rubin 95% Confidence Interval				
$\beta(p^{\text{fuel}})$	$(-\infty, -1.74] \cup [-0.67, \infty)$			

Notes: Excluded instruments are the Känzig (2021) oil supply news shock and its interaction with the PPI regime indicator. The endogenous regressors are p_t^{fuel} and $p_t^{\text{fuel}} \times \text{PPI}_t$; PPI_t enters as an exogenous regime indicator. First-stage F-statistics test joint significance of the excluded instruments. Wu-Hausman tests OLS exogeneity. Anderson-Rubin inference is robust to weak instruments. Sample: 2003:03–2020:02 ($n = 204$).

Table 15 reports reduced-form specifications that regress the real exchange rate directly on the oil supply news shock and its interaction with the PPI indicator. The exchange rate response to oil supply news is negligible and statistically indistinguishable from zero during the pre-PPI period ($\hat{\gamma} = 0.002$, $p = 0.77$). Under PPI, the interaction term is positive and significant ($\hat{\gamma}^{\text{int}} = 0.032$, $p = 0.016$), yielding a total estimated effect of 0.034. A positive supply news shock reduces oil prices; the positive coefficient on the exchange rate therefore signifies real depreciation, consistent with Brazil's exposure to oil-price movements through terms-of-trade and export-revenue channels under rule-based pricing.

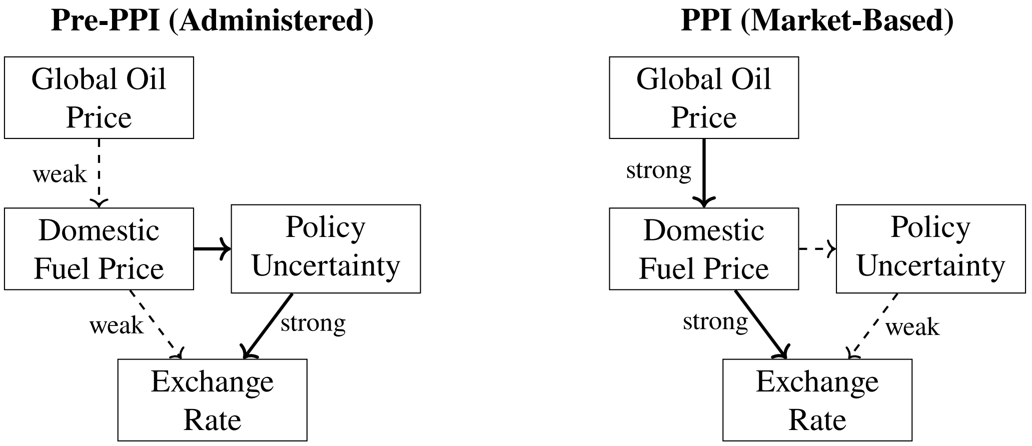
Table 15: Reduced-Form Regressions: Oil Supply Shocks and the Exchange Rate

	(1) OLS	(2) HAC(12)
Panel A: Supply Shock Effects		
Supply shock (Känzig)	0.0023	0.0023
	(0.0058)	(0.0076)
Supply shock × PPI	0.0318**	0.0318**
	(0.0127)	(0.0131)
PPI regime	−0.0571	−0.0571
	(0.0351)	(0.0702)
Panel B: Controls		
Interest rate differential	0.0134*	0.0134*
	(0.0039)	(0.0068)
Fuel volatility	0.1350	0.1350
	(0.0528)	(0.1230)
Fuel volatility × PPI	0.0059	0.0059
	(0.1061)	(0.1229)
Terms of trade (non-fuel)	−0.0019**	−0.0019**
	(0.0006)	(0.0008)
Cupom cambial spread (lag)	−0.0310***	−0.0310***
	(0.0042)	(0.0109)
VIX	−0.0020**	−0.0020
	(0.0008)	(0.0023)
CDS spread	0.0009***	0.0009***
	(0.0001)	(0.0002)
Panel C: Marginal Effects		
Effect of supply shock: Pre-PPI	0.002	[$p = 0.766$]
Effect of supply shock: PPI	0.034	[$p = 0.016$]
Difference (PPI − Pre-PPI)	0.032	[$p = 0.016$]
Observations	204	204
R^2	0.884	0.884

Notes: Dependent variable is $q_t = -\log(\text{REER}_t/100)$; positive values indicate depreciation. Supply shock is the Känzig (2021) oil supply news shock; positive values indicate increased oil supply. Column (1): HC1 robust standard errors. Column (2): Newey-West HAC with 12 lags and VAR(1) prewhitening. Sample: 2003:03–2020:02 (pre-COVID). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

The reduced-form pattern complements the transmission results in Section 5.2. Under administered pricing, oil supply news did not reach the exchange rate because domestic fuel prices were insulated from global markets. Under PPI, the same news transmits through the import-parity formula, producing a detectable exchange-rate response. That this increased market integration coexists with the volatility reductions in Table 4 indicates that the removal of discretionary intervention risk dominated the effect of greater commodity exposure on overall volatility.

Figure 9: Fuel Price Transmission Channels: Pre-PPI vs. PPI



Notes: Solid thick arrows indicate strong transmission; dashed arrows indicate weak or absent transmission. Under administered pricing, domestic prices were insulated from global markets but generated policy uncertainty that affected exchange rates. Under PPI, domestic prices track global markets directly, reducing the policy uncertainty channel.

C Unit Root and Cointegration Tests

Table 16 reports unit root and cointegration tests for the pre-COVID sample (2003:03–2020:02). The evidence is mixed. Johansen trace and Phillips-Ouliaris tests reject no cointegration at 10% significance, but the Engle-Granger statistic falls marginally short of the 10% critical value. For the full sample ending in May 2023, all three tests fail to reject no cointegration. These results motivate treating the levels relationship as an approximation rather than an established equilibrium condition. The main findings in Sections 5.2 and 5.4 do not require cointegration and are robust to first-difference specifications.

Table 16: Cointegration Tests: Pre-COVID Sample

	Test Statistic		Critical Values	
	Pre-COVID	Full Sample	5%	10%
Panel A: Unit Root Tests				
Fuel price (p^{fuel}) — ADF	-2.97^{**}	-3.51^{**}	-2.88	-2.57
Real exchange rate (q) — ADF	-2.26	-2.02	-2.88	-2.57
Real exchange rate (q) — PP	-2.86	-2.58	-2.88	-2.57
Panel B: Bivariate Cointegration (q, p^{fuel})				
Engle-Granger τ	-3.02	-1.80	-3.34	-3.04
Johansen trace ($r = 0$)	18.91^{*}	15.60	19.96	17.85
Phillips-Ouliaris	$p = 0.070^{*}$	$p = 0.150$	0.05	0.10
Panel C: Error Correction Model				
	Pre-COVID	Full Sample		
Speed of adjustment (ϕ)	-0.039^{*}	-0.019		
	(0.021)	(0.012)		
	[0.063]	[0.120]		
Long-run fuel effect (θ)	-0.008	-0.003		
	(0.010)	(0.006)		
	[0.407]	[0.658]		
Short-run fuel effect (δ)	-0.095^{***}	-0.096^{***}		
	(0.026)	(0.022)		
	[< 0.001]	[< 0.001]		
Observations	202	258		
Panel D: Multivariate Johansen (q, p^{fuel}, CDS, cupom)				
	Trace	5% CV	1% CV	Result
$r = 0$	89.82^{***}	53.12	60.16	Reject
$r \leq 1$	46.73^{***}	34.91	41.07	Reject
$r \leq 2$	16.83	19.96	24.60	Fail to reject
$\Rightarrow$ Two cointegrating vectors at 5% significance				

Notes: Pre-COVID sample: 2003:03–2020:02 ($n = 203$); Full sample: 2003:03–2023:05 ($n = 243$). Panel A: ADF includes constant; lag length by AIC. Panel B: Engle-Granger tests unit root in residuals from $q_t = \alpha + \beta p_t^{\text{fuel}} + u_t$; critical values from MacKinnon (2010). Johansen uses 2 lags, constant in cointegrating space. Panel C: ECM specification $\Delta q_t = \alpha + \phi q_{t-1} + \theta p_{t-1}^{\text{fuel}} + \delta \Delta p_t^{\text{fuel}} + \text{lags} + \varepsilon_t$; standard errors in parentheses, p-values in brackets. Panel D: Johansen trace test on 4-variable VAR(2). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

D Direct Evidence on the Policy Uncertainty Channel

The results in Sections 5.2–5.3 establish that PPI reduced exchange-rate and sovereign-risk volatility through a fuel-specific channel. A natural question is whether this stabilization reflects the removal of discretionary intervention risk, as the framework predicts, or concurrent developments such as the broader fiscal reform agenda in Brasil[6]. Petrobras equity prices offer a direct window into this question. Because Petrobras dominates domestic fuel distribution, its equity risk embeds forward-looking assessments of fuel-pricing policy; if discretionary pricing generated a measurable uncertainty premium, that premium should decline after October 2016 independently of broader fiscal developments.

The factor structure of Petrobras volatility reveals where the regime shift operates. We decompose the monthly realized volatility of PETR4 returns into contributions from observable risk factors. Column (1) of Table 17 reports the restricted model, in which the loading of $\sigma_t^{\mathrm{PETR4}}$ on the realized volatilities of Brent crude, the BRL/USD exchange rate, and the Ibovespa, together with the VIX index, is held constant across regimes. This specification yields an R^2 of 0.66, but the residual does not differ significantly across regimes ($p = 0.49$, Welch t-test), indicating that a constant-coefficient decomposition misses the relevant variation.

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[6] The fiscal reform agenda includes the constitutional expenditure ceiling (*teto de gastos*), enacted in December 2016 as Constitutional Amendment 95, which limited the real growth of federal primary expenditures for twenty years.

Table 17: Volatility Decomposition of Petrobras Returns

	Restricted (1)	Augmented (2)
σ^{Brent}	0.337^{***}	0.629^{***}
	(0.072)	(0.097)
$\sigma^{\text{Brent}} \times$ PPI		-0.713^{***}
		(0.138)
VIX	-0.011^{***}	-0.016^{***}
	(0.002)	(0.002)
VIX × PPI		0.016^{***}
		(0.004)
σ^{FX}	0.043	0.230
	(0.149)	(0.169)
$\sigma^{\text{FX}} \times$ PPI		−0.271
		(0.308)
σ^{Ibov}	1.422^{***}	1.224^{***}
	(0.104)	(0.135)
$\sigma^{\text{Ibov}} \times$ PPI		0.437^{**}
		(0.192)
PPI		-0.139^{**}
		(0.054)
R^2	0.659	0.729
Wald ($\delta_k = 0 \; \forall \; k$)		$p < 0.001$
Obs.	180	180

Notes: Dependent variable is the annualized standard deviation of daily PETR4 log returns within each month. Factor volatilities computed analogously from daily returns. VIX is the monthly average of the CBOE VIX index. Column (1) restricts factor loadings to be constant across regimes; column (2) allows regime-varying loadings via interactions with PPI_t. HC1 robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Allowing factor loadings to vary with the pricing regime reveals the source of this failure. Column (2) of Table 17 reports estimates from the augmented specification,

$$\sigma_t^{\text{PETR4}} = \alpha_0 + \alpha_1 \text{PPI}_t + \sum_k \left(\beta_k z_{k,t} + \delta_k \, z_{k,t} \times \text{PPI}_t \right) + \varepsilon_t, \tag{20}$$

where $z_{k,t} \in \{\sigma_t^{\text{Brent}}, \text{VIX}_t, \sigma_t^{\text{FX}}, \sigma_t^{\text{Ibov}}\}$.

Table 17 reports estimates from equation (20), where regime interactions are jointly significant ($p < 0.001$) and raise the R^2 to 0.73. Under administered pricing, the loading of PETR4 volatility on Brent volatility is large and positive ($\hat{\beta}_{\text{Brent}} = 0.629$, $p < 0.001$). Under PPI, this loading effectively vanishes ($\hat{\beta}_{\text{Brent}} + \hat{\delta}_{\text{Brent}} \approx -0.08$; $\hat{\delta}_{\text{Brent}} = -0.713$, $p < 0.001$). At the same time, the Ibovespa loading increases ($\hat{\delta}_{\text{Ibov}} = 0.437$, $p = 0.024$), indicating that Petrobras became more responsive to broad market conditions and less responsive to oil-specific uncertainty.

Under administered pricing, oil price movements carried information not only about Petrobras's production fundamentals but also about the likely trajectory of discretionary interventions and the associated fiscal transfers in equation (6). A rise in oil volatility signaled heightened uncertainty about whether the government would adjust prices, amplifying Petrobras equity risk beyond its direct commodity exposure. PPI rendered this anticipation channel largely irrelevant by tying adjustments to a predictable formula. The firm did not become insulated from oil markets; its return sensitivity to Brent increased. Oil uncertainty, however, ceased to generate excess volatility through the policy channel.

Rolling 60-day estimates of a two-factor model confirm this distinction. The mean oil beta rose from 0.14 pre-PPI to 0.24 under PPI, a 72% increase, while the model R^2 improved from 0.57 to 0.61 (Panel A of Table 18). Simultaneously, the ratio of PETR4 to Brent realized volatility fell from 1.58 to 1.33 ($p = 0.018$; Panel B). Petrobras became more correlated with oil in returns and less volatile relative to oil, the combination one expects when a policy-uncertainty wedge is removed.

Table 18: Petrobras Oil Sensitivity, Relative Volatility, and Surprise Frequency

	Pre-PPI	PPI	Difference
Panel A: Return sensitivity			
Mean $\hat{\beta}^{\text{Brent}}$	0.142	0.244	+0.102
	(0.142)	(0.162)	
Mean R^2	0.574	0.610	+0.036
Panel B: Relative volatility			
$\sigma^{\text{PETR4}}/\sigma^{\text{Brent}}$	1.579	1.327	-0.252^{**}
	(0.833)	(0.752)	$[p = 0.018]$
Panel C: Idiosyncratic surprise frequency			
$\overline{\text{SF}}_t$	0.054	0.030	-0.024^{***}
	(0.056)	(0.039)	$[p = 0.008]$
Mean $\lvert\hat{\eta}_t\rvert$ near adjustments	2.30%	1.81%	−0.49 pp
Mean $\lvert\hat{\eta}_t\rvert$ normal days	1.44%	1.30%	−0.14 pp
Monthly observations	101	79	

Notes: Panel A reports regime averages of rolling 60-day estimates of $r_t^{\text{PETR4}} = \alpha + \beta^{\text{Ibov}} r_t^{\text{Ibov}} + \beta^{\text{Brent}} r_t^{\text{Brent}} + \eta_t$; standard deviations of monthly coefficient estimates in parentheses. Panel B reports the ratio of monthly realized volatilities; p-value from a one-sided Welch t-test (H_1: Pre-PPI > PPI). Panel C defines the surprise frequency SF_t as the fraction of trading days per month with $|\hat{\eta}_t| > 2\hat{\sigma}_\eta$, where $\hat{\eta}_t$ is the residual from a full-sample market model; "near adjustments" denotes days within ±5 calendar days of a known fuel-price event. $^{***}p < 0.01$, $^{**}p < 0.05$.

A third piece of evidence comes from the frequency of large firm-specific return shocks. We define a surprise as a trading day on which the absolute abnormal return from a full-sample market model exceeds two standard deviations. The monthly surprise frequency SF_t fell from 5.4% of trading days under administered pricing to 3.0% under PPI, a decline of 44% ($t = 2.41$, $p = 0.008$; Panel C of Table 18). On days near known fuel-price adjustments, the mean absolute abnormal return exceeded that of normal days by 60% during administered pricing and by only 39% under PPI, consistent with rule-based pricing reducing the informational content of adjustment events.

These three findings converge on the same conclusion. Under administered pricing, oil-price uncertainty amplified Petrobras equity risk through the anticipation of discretionary interventions—a channel that operated independently of the firm's direct commodity exposure. PPI severed this link by tying price adjustments to a transparent formula. Petrobras became more sensitive to oil-price movements in returns while generating less excess volatility relative to those movements, and the frequency of large firm-specific shocks fell by nearly half. Because Petrobras's financial performance transmits to sovereign fiscal outcomes through ownership, dividends, and contingent liabilities, the suppression of this firm-level policy-uncertainty premium provides a direct micro-foundation for the sovereign-risk attenuation documented in Section 5.2.