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Structural Imbalances And Policy Distortions In Algeria's Refined Oil Products Market : An Empirical Analysis With Demand Elasticity Estimation

Desequilíbrios Estruturais e Distorções de Política no Mercado de Produtos Petrolíferos Refinados da Argélia: Uma Análise Empírica com Estimação da Elasticidade da Demanda

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Abstract

Algeria's refined oil products market exhibits a pronounced structural duality: the country is simultaneously one of Africa's major hydrocarbon exporters and a growing net importer of refined petroleum products. This paper extends the limited empirical literature on Algeria's downstream energy demand by estimating price and income elasticities specifically for refined petroleum products over 2000–2023 distinct from prior studies that focus on aggregate energy or CO_2–energy relationships. Using an ARDL (1,1,0,1) bounds-testing specification with three core regressors real fuel price index, real GDP per capita, and the registered vehicle fleet complemented by a real Brent crude price control to assess potential price endogeneity, we estimate a long-run price elasticity of −0.218 and an income elasticity of 0.872. Unit root tests (ADF and Phillips-Perron), multicollinearity diagnostics (VIF), and structural stability tests (CUSUM, CUSUMSQ) confirm the validity of the specification. The error correction term ECM (−1) = −0.312 indicates that approximately 31.2 percent of any deviation from long-run equilibrium is corrected annually, implying roughly three years for full demand adjustment to a price reform shock. Robustness is confirmed across six alternative specifications, including a Brent crude price control that shows minimal endogeneity bias. The econometric analysis is integrated with a comprehensive value-chain assessment of Algeria's refining and distribution system, a characterisation of four structural distortions administered pricing, fuel smuggling, refinery investment gaps, and fiscal sustainability concerns and comparative evidence from Kazakhstan, Iran, Egypt, and Indonesia. A graduated, rules-based price reform roadmap supported by targeted cash transfers is proposed as the most feasible pathway toward market normalisation.

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Resumo
O mercado de produtos petrolíferos refinados da Argélia apresenta um paradoxo estrutural: apesar de ser um dos principais exportadores de hidrocarbonetos da África, o país tornou-se um importador líquido crescente de produtos refinados. Este artigo estima as elasticidades-preço e elasticidades-renda da demanda argelina por produtos refinados no período 2000–2023, ampliando a literatura empírica prévia, que aborda apenas energia agregada ou relações CO_2–energia. Utilizando uma especificação de teste de limites ARDL (1,1,0,1) selecionada pelo Critério Bayesiano de Schwarz com índice real de preço de combustível, PIB per capita real e frota de veículos registrados como regressores centrais, estimamos uma elasticidade-preço de longo prazo de −0,218 e uma elasticidade-renda de 0,872. O termo de correção de erros ECM (−1) = −0,312 indica que aproximadamente 31% de qualquer desvio do equilíbrio de longo prazo é corrigido anualmente, implicando um horizonte de ajuste de cerca de três anos para uma reforma de preços. A robustez é confirmada em seis especificações alternativas, incluindo um controle pelo preço do petróleo Brent que confirma viés de endogeneidade negligenciável. Os resultados econométricos são integrados a uma avaliação da cadeia de valor do setor de refino argelino e a uma análise de quatro distorções estruturais: precificação administrada, contrabando de combustível, lacunas de investimento em refinarias e sustentabilidade fiscal. Evidências comparativas do Cazaquistão, Irã, Egito e Indonésia fundamentam um roteiro gradual e baseado em regras para a reforma de preços, apoiado por transferências diretas de renda como a via mais viável para a normalização do mercado.

1. Introduction

Algeria occupies a paradoxical position in the global energy landscape. As one of Africa's major natural gas exporters and a significant crude oil producer, its hydrocarbon wealth has long served as the principal engine of fiscal revenue, accounting for roughly 60–70 percent of state income and over 90 percent of merchandise export earnings (IMF, 2023). Yet, at the downstream end of the petroleum value chain, the country has become increasingly dependent on imported refined products an outcome that appears structurally incongruous given the scale of its upstream endowment.

This paradox is the cumulative product of a set of deeply embedded structural distortions: a refining sector whose expansion has chronically lagged behind surging domestic demand; a state-administered pricing mechanism that keeps retail fuel prices among the lowest in the world, insulated from international market signals; and a distributional framework shaped by rentier-state logic in which subsidised hydrocarbons function as a social contract between the government and the citizenry (Beblawi and Luciani, 1987; Aissaoui, 2016). Understanding these distortions their magnitude, their interactions, and their consequences for fiscal sustainability and market efficiency is the central motivation of this paper.

The urgency of this inquiry has intensified in recent years. The 2014–2016 oil price collapse exposed the fragility of Algeria's hydrocarbon-dependent fiscal model, prompting partial subsidy rationalisation measures that were subsequently softened under social and political pressure (World Bank, 2022). The post-2020 price recovery has temporarily relieved fiscal stress, but the structural trend of rising import dependence in refined products has continued unabated. Between 2000 and 2023, Algeria's refined products import bill expanded from approximately US$0.3 billion to over US$4.1 billion per annum a factor of thirteen in monetary terms straining foreign exchange reserves that declined from a peak of US$194 billion in 2014 to approximately US$62 billion by end-2023 (Banque d'Algérie, 2023), and imposing an increasingly visible opportunity cost on public finances.

Against this backdrop, the paper pursues four interconnected research objectives. First, it provides a systematic value-chain analysis of Algeria's refined oil products industry, documenting the supply-demand imbalance across gasoline, diesel, and LPG. Second, it characterises the market's operating mechanisms price administration, distribution infrastructure, and import/export regulation and identifies the principal structural challenges. Third, it estimates price and income elasticities of aggregate refined products demand over 2000–2023 using the ARDL bounds-testing methodology with full unit root, multicollinearity, and stability testing. Fourth, it draws on comparative evidence from Kazakhstan and Iran to construct a policy reform pathway appropriate to Algeria's institutional context.

This study makes three contributions to the existing literature. First, it extends the limited empirical literature on Algeria's energy demand by providing an updated elasticity estimation specifically for refined petroleum products over the 2000–2023 period longer and more recent than existing studies such as Bouznit and Pablo-Romero (2016), which focus on aggregate energy or CO_2 linkages rather than product-level refined fuels demand. Second, it integrates quantitative demand analysis with a detailed institutional description of the Algerian market, providing a richer analytical framework than either econometric-only or descriptive-only approaches. Third, it situates Algeria's structural challenge within a comparative framework of hydrocarbon-exporting states that have undertaken partial subsidy reform, generating actionable policy benchmarks. In addition, it provides a full set of econometric diagnostics including the explicit ARDL model form, short-run and long-run coefficients, error correction term, stability tests, and robustness checks that prior work on Algerian energy demand does not report.

2. Literature Review

The academic literature relevant to this paper spans three thematic pillars: the political economy of energy subsidies in rentier states, the empirical estimation of petroleum demand, and the economics of fuel smuggling and informal markets. Each strand contributes indispensable insights, and it is the integration of these strands rather than their isolated application that defines the analytical framework of this study.

The foundational concept of the rentier state, developed by Mahdavy (1970) and systematised by Beblawi and Luciani (1987), holds that states deriving the preponderance of their revenue from external rents particularly hydrocarbon revenues reproduce a specific political economy: citizens receive subsidised services and low taxation in exchange for political quiescence. In such states, cheap energy becomes not merely an economic policy instrument but a constitutive element of the implicit social contract between the ruling establishment and the population. Algeria's political economy conforms closely to this archetype (Martinez, 2010; Lowi, 2009).

The fiscal and allocative costs of energy subsidies have been extensively documented in the IMF literature. Coady et al. (2019) estimate that global pre-tax energy subsidies amounted to US$5.9 trillion in 2020, with the largest burdens borne by hydrocarbon-rich developing nations. In the MENA region specifically, Sdralevich et al. (2014) demonstrate that subsidies are regressive in their distributional incidence, disproportionately benefiting higher-income households who consume more fuel, while representing a major fiscal drain that crowds out productive public investment findings highly pertinent to the Algerian context, where the subsidy burden is estimated at 8–10 percent of GDP. More recent work by Rentschler and Bazilian (2017) and Cheon and Urpelainen (2018) identifies fiscal crisis as the primary catalyst for reform in developing economies, consistent with Algeria's partial reform attempt following the 2014–2016 oil price collapse.

The political economy of subsidy reform has received growing attention. Inchauste and Victor (2017) identify the conditions under which energy subsidy reforms succeed or fail, noting that gradualism, compensatory cash transfers, and institutional credibility are critical success factors findings directly informing the reform roadmap proposed in Section 7.

The estimation of petroleum product demand has a long tradition in the energy economics literature. The seminal meta-analysis by Dahl and Sterner (1991) surveys 50 gasoline demand studies and reports average long-run price and income elasticities of approximately −0.5 and 1.0 respectively, while noting substantial cross-country heterogeneity. Espey (1998) updates this survey with 101 studies, finding mean long-run price and income elasticities of −0.58 and 0.88. More recently, the comprehensive meta-analysis by Havranek et al. (2012), covering 312 estimates from 41 primary studies and applying publication bias correction, reports a corrected range of approximately −0.09 to −0.31 a range that directly brackets our Algerian estimate of −0.218 and confirms its plausibility within the cross-country evidence base.

Burke and Nishitateno (2013) examine the relationship between gasoline prices and consumption across 132 countries, confirming that price elasticities are substantially lower in oil-producing and subsidy-dependent economies. Sterner (2012) provides a comprehensive analysis of fuel taxation and demand, demonstrating that countries with low fuel taxes of which Algeria is an extreme case exhibit systematically lower price elasticity due to the insulating mechanism of subsidised prices, reinforcing the interpretation of our −0.218 estimate.

For developing and MENA economies, Medlock and Soligo (2001) model transportation energy demand as a function of income and vehicle ownership, finding strong non-linear income effects in rapidly motorising economies a framework directly applicable to Algeria, where the vehicle fleet expanded from approximately 2.8 million units in 2000 to over 6.7 million by 2023. Bakhat and Würzburg (2013) estimate energy demand elasticities for oil-exporting MENA countries using panel cointegration methods and find uniformly low-price elasticities (−0.05 to −0.20), attributing this to the insulating effect of subsidies on consumer price signals a result directly consistent with our Algerian estimate. The methodological choice of the ARDL bounds-testing procedure of Pesaran, Shin, and Smith (2001) has become the established standard for small-sample MENA energy demand studies for its capacity to handle mixed integration orders and simultaneously estimate short-run and long-run dynamics (Bekhet and Yusop, 2009).

For Algeria specifically, Bouznit and Pablo-Romero (2016) examine the relationship between energy consumption, CO_2 emissions, and economic growth, finding a significant long-run income-energy linkage. Aissaoui (2016), in a comprehensive study published by the Oxford Institute for Energy Studies, provides the most detailed analysis of Algeria's energy transition challenge to date. Our study builds on these foundations, extending the time horizon to 2023, disaggregating to the refined products level, and providing the short-run dynamics, multicollinearity diagnostics, and structural diagnostics that earlier studies do not report.

Large cross-border price differentials generate economically significant fuel smuggling flows in several MENA and Sub-Saharan economies. Coady et al. (2006) provide a theoretical and empirical framework demonstrating how subsidised fuel prices create arbitrage incentives exploited by informal cross-border trade networks, effectively exporting the subsidy burden to foreign consumers while inflating apparent domestic demand and depleting domestic supply. Barany and Grigonyte (2015) document analogous dynamics in Iran, where price differentials comparable in magnitude to Algeria's drove systematic fuel leakage to Pakistan, Turkey, and Afghanistan.

For Algeria, converging evidence from the IMF (2022), World Bank (2019) border trade analyses for the Sahel corridor, IEA (2022) regional energy accounts which reveal a systematic gap between apparent consumption and estimated final use in border regions and Mebtoul (2014) collectively support estimates of 15–25 percent leakage in border-adjacent regions, with aggregate national leakage of 5–10 percent of total consumption. Ross (2012) contextualises these dynamics within the broader resource curse literature, arguing that subsidised energy markets in oil-producing states create self-reinforcing perverse incentive structures that are politically difficult to dismantle.

The literature reviewed above converges on a common conclusion: Algeria's refined oil products market suffers from a set of interlocking distortions whose roots are political and institutional as much as they are technical or economic. Addressing them requires both rigorous empirical grounding which this paper provides and a clear-eyed assessment of reform feasibility, to which Section 7 is dedicated.

3. Algeria's Refined Oil Products Industry : Value Chain Analysis

3.1 Upstream: Crude Oil Production and Resource Base

Algeria's petroleum endowment is concentrated in the Saharan basins, with the Hassi Messaoud oil field and the Hassi R'Mel gas condensate complex representing the twin pillars of the country's hydrocarbon sector. Proven crude oil reserves stood at approximately 12.2 billion barrels as of end-2022 (BP Statistical Review, 2023). Sonatrach, the national oil company, controls the upstream sector under Law 05-07 of 2005 (as amended in 2013 and 2019), which reserves majority equity participation for Sonatrach in all upstream joint ventures.

Crude oil production peaked at approximately 1.98 million barrels per day (mb/d) in 2005, driven by joint ventures with major international oil companies. Since then, a combination of ageing field decline, under-investment in enhanced oil recovery, and periodic policy uncertainty has contributed to a declining production trend, with output falling to approximately 1.23 mb/d in 2023 a decline of roughly 38 percent from peak levels. This trajectory has critical fiscal implications: as crude production and export revenues decline, the opportunity cost of domestically consumed and subsidised refined products rises commensurately, compressing the fiscal headroom available to finance the subsidy.

3.2 Midstream: Refining Capacity, Configuration, and Output

Algeria's refining system comprises six operational refineries, the most significant of which are the Skikda refinery (capacity: 300,000 b/d), the Algiers refinery (60,000 b/d), the Arzew refinery (60,000 b/d), and the Hassi Messaoud topping plant (30,000 b/d). The most recently commissioned facility, the Tiaret refinery, adds approximately 50,000 b/d but had not reached full operational capacity as of 2023. Total nameplate refining capacity is approximately 700,000 b/d, while actual throughput has been in the range of 540,000–560,000 b/d, implying a utilisation rate of approximately 78–80 percent well below efficient benchmarks of 90–95 percent (IEA, 2022).

The configuration of the Algerian refining system creates a structural mismatch between the product slate produced and the pattern of domestic demand. The Skikda refinery is oriented primarily toward fuel oil and vacuum gas oil production, reflecting its 1970s–1980s vintage design. Investment in secondary conversion units fluid catalytic crackers and hydrocrackers that would increase yields of high-demand products such as gasoline and diesel has chronically lagged behind demand growth. The consequence is a refinery output profile that systematically under-produces the middle and light distillates most demanded by Algerian consumers, necessitating imports even when crude throughput is adequate.

3.3 Downstream: Supply-Demand Balance by Product

Table 1 presents Algeria's key crude oil and refining indicators for selected benchmark years, documenting the sustained decline in crude production alongside a growing gap between refining capacity and domestic product requirements.

Table 1. Algeria: Key Crude Oil and Refining Indicators

Indicator	2000	2005	2010	2015	2023
Crude Oil Production (mb/d)	1.578	1.985	1.809	1.584	1.230
Crude Oil Exports (mb/d)	0.828	1.043	0.870	0.734	0.560
Refining Capacity (mb/d)	0.457	0.457	0.575	0.650	0.700
Refinery Throughput (mb/d)	0.381	0.395	0.432	0.506	0.550
Refinery Utilisation Rate (%)	83.4	86.4	75.1	77.8	78.6
Number of Operational Refineries	5	5	5	5	6
Net Oil Export Revenue (US$ bn)	12.3	27.9	44.4	34.6	36.5

***Sources**: OPEC Annual Statistical Bulletin (various years); BP Statistical Review of World Energy 2023; IEA World Energy Statistics 2023; Sonatrach Annual Reports. mb/d = million barrels per day. Full annual series in Appendix A.*

Table 2 presents the supply-demand balance across gasoline, diesel, and LPG for selected years from 2005 to 2023. The data reveals a secular deterioration in the self-sufficiency position of each product category, driven by population growth, rising per capita income, rapid motorisation, and heavily subsidised retail prices.

Table 2. Algeria: Refined Products Supply-Demand Balance, (kilotonnes)

Product	2005	2010	2015	2020	2023
Gasoline – Production (kt)	4,210	4,890	5,640	6,120	6,870
Gasoline – Domestic Demand (kt)	3,760	4,950	6,210	7,340	8,450
Gasoline – Balance (kt)	+450	−60	−570	−1,220	−1,580
Diesel – Production (kt)	7,320	8,100	9,250	9,870	10,450
Diesel – Domestic Demand (kt)	6,840	8,560	10,410	12,180	14,230
Diesel – Balance (kt)	+480	−460	−1,160	−2,310	−3,780
LPG – Production (kt)	2,630	2,980	3,210	3,450	3,600
LPG – Domestic Demand (kt)	2,420	3,040	3,680	4,250	4,890
LPG – Balance (kt)	+210	−60	−470	−800	−1,290
Total Products Imports (kt)	820	2,100	4,350	6,800	9,200
Import Bill (US$ million)	310	1,050	2,870	1,890	4,100

***Sources**: OPEC Annual Statistical Bulletin (various years); IEA World Energy Statistics 2023; authors' compilation and interpolation where annual observations were unavailable (see Appendix A). Apparent domestic consumption = production + imports − exports ± stock changes. Negative balances indicate net import requirements.*

The structural surplus in gasoline that characterised the early 2000s was fully eroded by 2010 and had expanded to a deficit of approximately 1,580 kt by 2023. The diesel imbalance is more pronounced: from a marginal surplus of 480 kt in 2005, the sector shifted to a deficit of 3,780 kt in 2023 a near eight-fold deterioration in less than two decades. Across all three products, total refined imports grew from approximately 820 kt in 2005 to an estimated 9,200 kt in 2023, with the associated import bill expanding from US$310 million to over US$4.1 billion. By 2023, Algeria was importing approximately 35 percent of its total refined products requirement a structurally incongruous figure for a country with substantial upstream crude endowment, and broadly comparable to Iran during its most severe fuel import crisis in the mid-2000s.

Several structural factors underpin this demand escalation. The Algerian vehicle fleet grew at a compound annual rate of approximately 5.7 percent between 2000 and 2023, reaching an estimated 6.7 million registered vehicles. GDP per capita expanded steadily, sustaining purchasing power and discretionary mobility demand. Critically, real retail fuel prices adjusted for inflation declined over the period as nominal prices were held largely stable while the general price level rose, further stimulating consumption and reducing incentives for fuel efficiency improvements.

4. Market Operating Mechanisms

4.1 Circulation and Distribution Framework

The distribution of refined oil products in Algeria operates under a vertically integrated state structure in which Naftal, a wholly owned subsidiary of Sonatrach, retains control over wholesale distribution, primary storage infrastructure, and the operation of the principal retail network. Naftal manages an estimated 3,200 service stations across the country, supplemented by approximately 1,800 privately operated stations that purchase products at regulated wholesale prices. The pipeline infrastructure linking refineries to regional distribution hubs is relatively well-developed in the northern and central zones, though coverage in the deep south remains sparse, creating logistical bottlenecks and elevating effective supply costs in Saharan regions.

The distribution margin structure is administratively set and has not been adjusted to reflect rising operational costs in recent years, contributing to deteriorating financial viability for private station operators and disincentivising network expansion in underserved areas. Storage capacity is estimated at approximately 3.5 million cubic metres for finished products, covering roughly 60 days of consumption a buffer adequate under normal conditions but insufficient during periods of supply disruption or import delivery delays. The overall distribution architecture reflects a system designed for the supply conditions of the 1980s and early 1990s, and has not been fundamentally restructured to accommodate the more than threefold increase in product volumes that has occurred since that period.

4.2 Price Distortions in the Domestic Fuel Market and Subsidy Structure

The administered pricing of refined petroleum products is the most consequential structural feature of Algeria's downstream energy market. Retail prices for all major products gasoline, diesel, LPG, and fuel oil are set by executive decree and have remained far below both international market levels and domestic economic cost estimates throughout the period under study. Table 3 provides a comparative perspective on Algerian retail fuel prices relative to selected regional comparators and the world average.

Table 3. Comparative Retail Fuel Prices and Implicit Subsidy Estimates, 2023

Country / Indicator	Gasoline (US¢/litre)	Diesel (US¢/litre)	LPG (US$/cylinder)	Price Index (World=100)
Algeria (2023)	36	21	1.40	18
Iran (2023)	4	2	0.20	3
Egypt (2023)	42	34	3.90	27
Tunisia (2023)	115	98	8.50	74
Saudi Arabia (2023)	62	23	3.00	29
World Average (2023)	173	165	17.50	100

Algeria – Economic Cost (import parity)	~148	~130	~15.00	—
Implicit Subsidy per Litre (US¢)	~112	~109	~13.60	—

***Sources**: GlobalPetrolPrices.com (2023); IEA Energy Prices and Taxes (2023); IMF Staff Country Reports; authors' calculations. Economic cost estimate based on import parity pricing methodology. World average from GlobalPetrolPrices.com weighted mean.*

At US$0.36 per litre for gasoline and US$0.21 per litre for diesel, Algerian pump prices represent approximately 18 percent of the world average exceeded in their degree of subsidy only by Iran. Aggregated across total consumption volumes, these implicit subsidies translate to a fiscal and quasi-fiscal cost in the range of US$13–18 billion per annum, representing approximately 8–10 percent of GDP consistent with IMF Article IV estimates (IMF, 2022, 2023).

The subsidy is financed through a combination of mechanisms. First, Sonatrach supplies refined products to Naftal at below-market transfer prices, effectively cross-subsidising the downstream sector from upstream export revenues. Second, direct budgetary allocations cover residual price support costs. Third, the state assumes the full cost of imported products at international prices while distributing them domestically at subsidised retail rates, generating a structural quasi-fiscal deficit within Sonatrach's accounts. This multi-layered structure makes the total subsidy cost difficult to calculate from public accounts and contributes to the opacity that has historically impeded reform efforts.

4.3 Import, Export, and Regulatory Framework

Sonatrach holds a statutory monopoly on crude oil and refined products exports, while imports of refined products are managed through either direct Sonatrach procurement or licensed intermediaries subject to Ministry of Energy approval. This framework ensures state control over the import process but introduces administrative bottlenecks and limits the development of a competitive wholesale market. No domestic futures or forward markets for refined products exist. The Algerian dinar is not freely convertible, and the official exchange rate has historically been maintained at a premium to the parallel market rate adding an additional layer of price distortion by undervaluing the foreign exchange cost of imports when translated into domestic currency terms.

The regulatory framework governing petroleum product quality has been progressively aligned with Euro 2 and Euro 4 standards for motor fuels, though enforcement varies. Investment in refinery desulphurisation and reforming units necessary to meet Euro 5 standards required for Algeria to remain a credible supplier to European markets has been slow, adding a further dimension to the investment case for refinery modernisation that extends beyond domestic supply adequacy.

5. Key Structural Challenges

5.1 Price Distortions in the Domestic Fuel Market

The most fundamental structural challenge facing Algeria's refined products market is the absence of any mechanism by which prices convey scarcity or cost information to consumers. With retail prices fixed by decree at levels representing a fraction of economic cost, consumer behaviour is shaped entirely by income and access constraints rather than by price signals. The econometric results reported in Section 6 confirm this: the long-run price elasticity of demand of −0.218, while statistically significant, is substantially lower than estimates for comparable economies with less distorted price structures, indicating that the subsidy regime successfully insulates consumer behaviour from cost reality.

Partial rationalisation measures introduced in 2015–2016 which raised fuel prices modestly in response to the fiscal crisis triggered by the oil price collapse were reversed under social and political pressure, demonstrating the path-dependent nature of subsidy regimes in rentier states (Ross, 2012). The challenge is not merely technical but deeply political: energy subsidies have been the cornerstone of the social contract for over four decades, and their removal is perceived by large segments of the population as a breach of state obligations.

5.2 Fuel Smuggling and Cross-Border Leakage

The price differential between Algerian domestic prices and those prevailing in neighbouring countries Tunisia, Libya, Niger, and Mali creates powerful economic incentives for cross-border arbitrage. Based on estimates from the IMF (2022), World Bank (2019) border trade analyses, IEA (2022) regional accounts, and Mebtoul (2014), fuel smuggling is estimated to account for 15–25 percent of effective consumption in border regions, with aggregate leakage across all products potentially representing 5–10 percent of total national consumption.

The economic mechanics are straightforward. A litre of diesel priced at US$0.21 in Algeria can be resold for approximately US$0.98–1.10 in neighbouring markets, yielding gross arbitrage margins exceeding 350 percent sufficient to sustain sophisticated informal distribution networks that have proved resistant to enforcement efforts. The consequence for the domestic market is threefold: subsidised product intended for Algerian consumers is effectively exported at zero price, domestic apparent demand is inflated relative to genuine domestic final consumption, and the fiscal cost of the subsidy is partially transferred to the benefit of foreign consumers and informal intermediaries.

5.3 Infrastructure Constraints and Refinery Investment Gap

The structural deficit between refinery output and domestic demand documented in Section 3 reflects not primarily a shortage of crude feedstock which is abundantly available but chronic under-investment in refinery conversion capacity and modernisation. Sonatrach has repeatedly announced refinery expansion and upgrade programmes that experienced significant delays and cost overruns. Planned hydrocracker installations at Skikda have been deferred multiple times. The consequence is that the refinery configuration remains oriented toward a product slate that no longer matches the composition of domestic demand.

Private investment in the downstream sector is structurally disincentivised by the administered pricing regime: no private operator can earn a market return on refinery investment when products must be sold at regulated prices set below cost recovery levels. The state's monopoly over distribution further limits the value that a private refiner could capture. Until pricing and distribution reform creates a commercially viable downstream environment, the investment gap will persist, and import dependence will continue to grow. Investment in hydrocracker and desulphurisation units is also essential for maintaining access to European product export markets under tightening quality standards, adding a further dimension to the reform imperative.

5.4 Fiscal Sustainability and Investment Attractiveness

The confluence of declining crude production, growing domestic consumption of subsidised products, and rising import costs creates a trajectory that is fiscally unsustainable below approximately US$90 per barrel. Algeria's foreign exchange reserves declined from approximately US$194 billion in 2014 to approximately US$62 billion by end-2023, partly reflecting this structural erosion (Banque d'Algérie, 2023).

The investment environment for the upstream sector which ultimately finances the downstream subsidy regime has also attracted limited foreign direct investment relative to its resource potential, reflecting concerns about contract security, bureaucratic barriers, and the opacity of the fiscal regime. A vicious cycle is emerging: declining upstream investment constrains production growth, which reduces fiscal space, which limits the government's capacity to finance the transition away from subsidy dependence, which in turn perpetuates the conditions that deter downstream private investment.

6. Econometric Analysis : Demand Elasticity Estimation

6.1 Data and Variable Construction

Annual data from 2000 to 2023 (T = 24 observations) were compiled from multiple authoritative sources and cross-validated. Table 4 provides the explicit variable definitions, measurement units, and primary data sources. A key addition relative to a standard fuel demand specification is the real Brent crude oil price (BRENT) as an exogenous control in robustness Model M5. Because Algerian fuel prices are policy-determined, they may respond to fiscal pressures partly correlated with consumption trends, generating potential endogeneity between PRICE and DEMAND. Including the globally exogenous Brent price allows assessment of whether the core price elasticity is sensitive to this concern.

Table 4. Variable Definitions, Measurement Units, and Primary Data Sources

Variable	Definition	Measurement Unit	Primary Source(s)
DEMAND	Apparent domestic consumption (production + imports − exports ± stocks)	Kilotonnes per year	OPEC ASB (primary); IEA WES (cross-validation)
PRICE	Weighted-avg. real retail price index (gasoline 38%, diesel 52%, LPG 10%), CPI-deflated	Index, 2015=100	GlobalPetrolPrices.com; ONS Algeria; Ministry of Energy
GDPPC	Real GDP per capita, constant 2015 US dollars	US$ per person	World Bank WDI (NY.GDP.PCAP. KD)
VEHICLES	Total registered motor vehicles (cars, trucks, motorcycles)	Thousands of units	ONS Algeria Annuaire Statistique; IRF World Road Statistics
BRENT	Real Brent crude price (nominal/US CPI) — exogeneity control, M5 only	Index, 2015=100	EIA; IMF IFS
SUBSIDY	Pre-tax energy subsidy / GDP — robustness only	Percent of GDP	IMF Art. IV Reports; Coady et al. (2019)

OPEC ASB = OPEC Annual Statistical Bulletin. IEA WES = IEA World Energy Statistics. ONS = Office National des Statistiques Algeria. IRF = International Road Federation. WDI = World Bank World Development Indicators. EIA = U.S. Energy Information Administration. Full annual data series with source flags and interpolation notes are provided in Appendix A, Table A1.

Where annual observations were missing from a single source, linear interpolation was applied between benchmark observations. For 2021–2022, preliminary IEA estimates were used and cross-validated against Sonatrach Annual Reports;

discrepancies did not exceed 2.3 percent in any year. All interpolated observations are flagged in Appendix A.

6.2 Model Specification

The empirical analysis employs the ARDL bounds-testing procedure of Pesaran, Shin, and Smith (2001) to estimate long-run and short-run price and income elasticities of refined oil products demand. The ARDL framework is preferred over Johansen cointegration for three reasons specific to this application: (1) with T = 24, the asymptotic assumptions underlying Johansen's maximum likelihood estimator are not satisfied; (2) the regressors include variables of mixed integration order I(0)/I(1), rendering Johansen inapplicable; and (3) the ARDL framework simultaneously estimates short-run dynamics and the long-run equilibrium relationship.

To avoid over-fitting with T = 24, the baseline specification employs three core regressors:

$$\ln(DEMAND_t) = \alpha + \beta_1 \ln(PRICE_t) + \beta_2 \ln(GDPPC_t) + \beta_3 \ln(VEHICLES_t) + \varepsilon_t$$

The Schwarz Bayesian Information Criterion selects ARDL (1,1,0,1) as the optimal lag structure: one lag on ln(DEMAND), one distributed lag on ln(PRICE), zero additional lags on ln(GDPPC), and one additional lag on ln(VEHICLES). The error correction representation is:

$$\Delta\ln(DEMAND_t) = \alpha + ECM(-1) \cdot [\ln(DEMAND_{t-1}) - \beta_1 \ln(PRICE_{t-1}) - \beta_2 \ln(GDPPC_{t-1}) - \beta_3 \ln(VEHICLES_{t-1})] + \gamma_1 \Delta\ln(PRICE_t) + \gamma_2 \Delta\ln(GDPPC_t) + \gamma_3 \Delta\ln(VEHICLES_{t-1}) + \upsilon_t$$

ECM (−1) measures the annual speed of reversion to long-run equilibrium. A negative and statistically significant ECM (−1) is required to confirm cointegration (Banerjee et al., 1998). All continuous variables enter in natural logarithms, so coefficients are directly interpretable as elasticities. SUBSIDY and DUMMY_2015 are included only in extended robustness specifications.

6.3 Unit Root Tests

Table 5 presents results from both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Lag length for the ADF test was selected using the Akaike Information Criterion with a maximum of four lags; the bandwidth for the PP test was determined by the Newey-West automatic method. Both tests include an intercept but no deterministic trend. Results confirm the mixed integration order required for ARDL application.

Table 5. Unit Root Test Results: ADF and Phillips-Perron

Variable	ADF Level (t-stat)	ADF 1st Diff (t-stat)	PP Level (t-stat)	PP 1st Diff (t-stat)	Integration Order
ln(DEMAND)	−1.42	−4.18***	−1.38	−4.31***	I(1)
ln(PRICE)	−1.87	−3.96***	−1.92	−4.07***	I(1)
ln(GDPPC)	−0.93	−4.52***	−0.88	−4.64***	I(1)
ln(VEHICLES)	−1.15	−3.88***	−1.10	−4.01***	I(1)
ln(BRENT)	−1.61	−4.22***	−1.58	−4.33***	I(1)
SUBSIDY	−2.91**	—	−3.04**	—	I(0)
5% Critical Value	−2.998	−2.998	−2.998	−2.998	—

*ADF = Augmented Dickey-Fuller (Said and Dickey, 1984). PP = Phillips-Perron (Phillips and Perron, 1988). 5% critical value ≈ −2.998 (MacKinnon, 1996). Significance codes: *** p<0.01; ** p<0.05; * p<0.10. This convention is applied uniformly across all tables in this paper.*

6.4 Multicollinearity Diagnostics

GDP per capita and vehicle fleet size are structurally correlated rising income directly drives vehicle ownership. The potential for multicollinearity was assessed via Variance Inflation Factor (VIF) analysis and the Pearson correlation matrix. Table 6 reports the results.

Table 6. Multicollinearity Diagnostics: VIF and Correlation

Variable	VIF	Tolerance	Assessment
ln(PRICE)	2.13	0.469	No concern (VIF well below 10)
ln(GDPPC)	4.81	0.208	Acceptable (VIF below 10 threshold)
ln(VEHICLES)	5.03	0.199	Acceptable (VIF below 10 threshold)
Mean VIF	4.00	—	No problematic multicollinearity
Pearson r: GDPPC × VEHICLES	—	0.847	High but VIF below critical threshold

VIF = Variance Inflation Factor = $1/(1-R^2_j)$. Tolerance = 1/VIF. The formal threshold for concern is VIF > 10 (Belsley, Kuh, and Welsch, 1980; Kennedy, 2008); the threshold of 5 sometimes cited in introductory treatments is a conservative heuristic, not a statistical criterion. All values in the core model fall below 5.03, substantially below the diagnostic threshold. Empirical confirmation that multicollinearity does not distort the estimates is provided by Models M2 and M3 in Table 10, which show that excluding either ln(GDPPC) or ln(VEHICLES) shifts the remaining elasticity by less than one standard error of the baseline.

6.5 ARDL Bounds Test and Structural Break Testing

Table 7 reports the ARDL bounds test results alongside formal tests for structural breaks. The model includes DUMMY_2015 as a level-shift control in the extended specification (M4, Table 10); to justify this choice against the alternative of a full parameter break, we apply both the Chow test at the known candidate break point (2015) and the Quandt-Andrews sup-F test for an unknown break across the trimmed sample.

Table 7. ARDL Bounds Test and Structural Break Results

Test / Statistic	Value	Decision
F-statistic — Bounds Test	5.72	Cointegration confirmed
Lower Critical Bound I(0), 5%	3.23	—
Upper Critical Bound I(1), 5%	4.35	—
Optimal ARDL Model (SBC)	ARDL (1,1,0,1)	—
Number of Observations (T)	24 (2000–2023)	—
Regressors in bounds test (k)	3 (core model)	—
Chow Test F-statistic (break at 2015)	2.14	No structural break (5% c.v. ≈ 2.77)
Quandt-Andrews sup-F statistic	3.87	No unknown break (5% c.v. = 7.18)

*Critical values from Pesaran, Shin, and Smith (2001), Table CI(iii), Case III (unrestricted intercept, no trend). Chow test examines parameter stability across the 2000–2015 and 2016–2023 sub-periods; the null of parameter constancy is not rejected at the 5% level (F (4,16) critical value ≈ 2.77). The Quandt-Andrews sup-F test covers the trimmed range 15%–85% (Andrews, 1993); the null of no unknown structural break is not rejected. Inclusion of DUMMY_2015 in the extended model (M4) is therefore statistically justified as a level-shift control rather than evidence of a parameter break. Significance codes: *** p<0.01; ** p<0.05; * p<0.10. SBC = Schwarz Bayesian Criterion.*

The F-statistic of 5.72 substantially exceeds the upper critical bound of 4.35 at the 5 percent significance level, confirming the existence of a long-run cointegrating relationship among ln(DEMAND), ln(PRICE), ln(GDPPC), and ln(VEHICLES). This cointegration implies that the variables move together in the long run and that the estimated long-run coefficients are superconsistent. The structural break tests further establish that this long-run relationship is stable across the full sample period, validating full-sample estimation and confirming that the DUMMY_2015 specification is the appropriate treatment of the 2015–16 price adjustment episode.

6.6 Diagnostic Tests and Stability

Table 8 reports model diagnostic statistics. All tests confirm the validity and reliability of the estimated model. The CUSUM and CUSUM-of-Squares statistics (Brown, Durbin, and Evans, 1975) remained within the 5 percent significance bounds throughout the sample period, confirming parameter and variance stability. The graphical CUSUM and CUSUM-of-Squares plots are provided in Appendix B (Figures B1 and B2) to allow direct visual verification of parameter stability, consistent with the transparency standards recommended for applied time series work. These results imply that the estimated elasticities are not driven by any particular sub-period and are appropriate for forward-looking policy projection.

Table 8. Model Diagnostic Statistics

Diagnostic Test	Statistic / p-value	Interpretation
Breusch-Godfrey LM Test (p-value)	0.412	No serial correlation
Engle ARCH Test (p-value)	0.638	No conditional heteroscedasticity
Jarque-Bera Normality Test (p-value)	0.317	Residuals approximately normal
Ramsey RESET Test (p-value)	0.284	No functional form misspecification
CUSUM Test	Within 5% bounds	Parameter stability confirmed
CUSUM-of-Squares Test	Within 5% bounds	Variance stability confirmed
Adjusted R^2 (core 3-regressor model)	0.929	Consistent with MENA demand literature

LM = Breusch-Godfrey Lagrange Multiplier. ARCH = Engle's autoregressive conditional heteroscedasticity test. RESET = Ramsey Regression Equation Specification Error Test. Adjusted R^2 of 0.929 is consistent with MENA demand literature (cf. Bakhat and Würzburg, 2013, reporting 0.87–0.94 for oil-exporting MENA economies).

6.7 Long-Run and Short-Run Coefficient Estimates

Table 9 presents the full ARDL (1,1,0,1) estimation results, including long-run coefficients, short-run dynamics, and the error correction term, together with the extended robustness specification.

Table 9. ARDL (1,1,0,1) Estimation: Long-Run, Short-Run, ECM, and Extended Model

Variable	Coefficient	Std. Error	t-Statistic	Significance
Long-Run Coefficients				
ln(PRICE)	−0.218	0.067	−3.25	***
ln(GDPPC)	0.872	0.098	8.90	***
ln(VEHICLES)	0.641	0.119	5.39	***
Constant (α)	−3.247	0.441	−7.36	***
Short-Run Coefficients				
Δln(PRICE)t	−0.068	0.029	−2.34	**
Δln(GDPPC)t	0.272	0.084	3.24	***
Δln(VEHICLES)t−1	0.198	0.077	2.57	**

— ERROR CORRECTION —				
ECM(−1)	−0.312	0.091	−3.43	***
EXTENDED MODEL (With SUBSIDY & DUMMY_2015)				
ln(PRICE) — extended	−0.209	0.071	−2.94	***
SUBSIDY — extended	0.183	0.071	2.57	**
DUMMY_2015 — extended	−0.068	0.028	−2.41	**
Adj. R^2 extended model	0.937	—	—	—

*Dependent variable: Δln (Total Refined Products Demand, kilotonnes). ARDL (1,1,0,1) selected by SBC. Sample: 2000–2023 (T=24). Standard errors are heteroscedasticity-robust (HC1). Significance codes: *** p<0.01; ** p<0.05; * p<0.10.*

The estimated long-run price elasticity of −0.218 (t = −3.25, p < 0.01) implies that a sustained 10 percent increase in real retail fuel prices would reduce long-run consumption by approximately 2.18 percent. This estimate falls squarely within the range of −0.09 to −0.31 reported in the publication-bias-corrected meta-analysis of Havranek et al. (2012), and is consistent with Bakhat and Würzburg (2013) for oil-exporting MENA economies (−0.05 to −0.20).

Rather than interpreting the low-price elasticity as a weakness of the model or a data artefact, we argue that it constitutes an empirically meaningful finding in its own right. The historical variation in real fuel prices in Algeria is driven predominantly by CPI inflation eroding a fixed nominal price not by discrete nominal price adjustments that would generate salient behavioural signals. The estimated −0.218 therefore captures the demand response to a gradual, inflationary erosion of real purchasing power in the absence of any visible price shock. This is theoretically distinct from the response that would obtain under an explicit nominal price reform. As Sterner (2012) and Burke and Nishitateno (2013) demonstrate, subsidy-maintained pricing environments generate structural demand insensitivity: the absolute nominal change required to induce a given proportional response is diluted by the artificially low baseline price level. The implication directly relevant to policy design is that the estimated elasticity of −0.218 is best interpreted as a lower bound on the demand reduction achievable through an explicit, salient nominal price reform. Evidence from comparable reform episodes in Egypt and Kazakhstan is consistent with this interpretation: both achieved demand responses exceeding their pre-reform elasticity estimates once discrete nominal adjustments were announced.

The long-run income elasticity of 0.872 (t = 8.90, p < 0.01) confirms that rising per capita income is the dominant driver of demand growth. A 1 percent increase in real GDP per capita generates a 0.87 percent increase in long-run refined products consumption, reflecting the continued expansion of motorisation, commercial transport, and energy-intensive economic activity at Algeria's stage of development. The vehicle fleet coefficient of 0.641 (t = 5.39, p < 0.01) is an independent and quantitatively significant driver of demand even after controlling for income, consistent with Medlock and Soligo (2001).

The ECM (−1) of −0.312 (t = −3.43, p < 0.01) is negative, less than unity in absolute value, and highly significant satisfying all conditions for valid cointegration (Banerjee et al., 1998). Approximately 31.2 percent of any deviation from long-run equilibrium is corrected within one year; the half-life of a deviation is approximately 1.9 years, and approximately 87 percent of adjustment is completed within three years. This three-year adjustment horizon has direct implications for the phasing of pricing reform: reform effects on demand will materialise gradually, and packages should be designed with this temporal structure in mind.

The short-run price elasticity of −0.068 indicates that the immediate within-year demand response to a price change is only about 31 percent of the long-run equilibrium response, reflecting the rigidity of short-run fuel consumption behaviours particularly commuting patterns, existing vehicle stock, and the absence of viable fuel substitutes. The extended model confirms that core elasticities remain essentially stable when SUBSIDY and DUMMY_2015 are added: the long-run price elasticity shifts from −0.218 to −0.209, well within one standard error of the baseline estimate.

6.8 Robustness Checks

Table 10 presents six robustness specifications. The price elasticity estimate ranges narrowly from −0.203 to −0.241 across M1–M5, demonstrating robust stability. In Model M5, the Brent crude price coefficient is small and statistically insignificant (0.031, n.s.), while the core price elasticity shifts marginally from −0.218 to −0.211 well within one standard error suggesting that potential endogeneity of the administered price variable does not materially bias the core estimate. Model M6 in first differences yields a lower adjusted R^2 of 0.612, confirming that the high goodness-of-fit in M1–M5 reflects genuine long-run cointegration rather than spurious correlation.

Table 10. Robustness Checks: Six Alternative Specifications

Specification	ln(PRICE) Coeff.	ln(GDPPC) Coeff.	ln(VEHICLES) Coeff.	ln(BRENT) Coeff.	Adj. R^2
M1: Core ARDL (1,1,0,1)	−0.218***	0.872***	0.641***	—	0.929
M2: Income only (PRICE + GDPPC)	−0.241***	1.103***	—	—	0.891
M3: Mobility only (PRICE + VEHICLES)	−0.203***	—	0.781***	—	0.918
M4: Core + SUBSIDY + DUMMY_2015	−0.209***	0.858***	0.634***	—	0.937
M5: Core + BRENT (endogeneity ctrl.)	−0.211***	0.864***	0.638***	0.031 n.s.	0.931
M6: First-differences (short-run only)	−0.071**	0.287***	0.203**	—	0.612
Meta-analytic benchmark (Havranek et al., 2012)	−0.09 to −0.31	—	—	—	—

*Significance codes: *** p<0.01; ** p<0.05; * p<0.10; n.s. = not significant at 10%. Convention is uniform across all tables.*

6.9 Limitations

Four limitations merit explicit acknowledgment, together with an assessment of their likely magnitude.

Interpolation and data quality. More than 70 percent of the PRICE observations and approximately 40 percent of the VEHICLES observations in the annual dataset are obtained by linear or log-linear interpolation between confirmed benchmark values (see Appendix A, Table A1). Interpolation of this extent introduces artificial smoothness into both series, which can generate spurious autocorrelation in the residuals, inflate R^2, and reduce the power of unit root tests by attenuating high-frequency variation. The Breusch-Godfrey LM test (p = 0.412) provides reassurance against serial correlation in the estimated model, but cannot fully rule out interpolation-induced smoothing bias. As a partial robustness check, we re-estimated the core model using only the 10 years with direct observations on both PRICE and VEHICLES (2005, 2008, 2010, 2015, 2016, 2018, 2020, 2022 and two additional benchmarks); coefficient signs and approximate magnitudes were preserved, though standard errors widened as expected with the reduced sample. Full sensitivity results are available from the authors upon request.

Price variance and the nature of the PRICE signal. The variation in the real PRICE index over 2000–2023 is driven almost entirely by CPI inflation eroding a largely fixed nominal price not by discrete nominal price adjustments. This means that the PRICE regressor captures inflationary erosion of purchasing power rather than salient nominal price signals of the kind that typically induce behavioural adjustment. As a consequence, the estimated long-run price elasticity of −0.218 is best interpreted as a lower bound on the demand response to an explicit, visible nominal price reform. A discrete administered price increases the mechanism relevant to any reform scenario would generate stronger salience effects than the gradual real erosion captured in the historical data. The policy implication is that the demand reduction projections in Table 12 (Section 7.2) are conservative estimates of the likely response to a reform package.

Smuggling bias in the dependent variable. The DEMAND variable represents apparent domestic consumption, constructed from the standard production-plus-imports-minus-exports identity. It therefore includes volumes that cross borders as smuggled fuel and are consumed abroad. To the extent that smuggling volumes are correlated with the vehicle fleet and income growth in border regions, this introduces an upward bias in the estimated income and vehicle fleet elasticities, and inflates the apparent level of domestic consumption relative to genuine final use. The direction and magnitude of this bias cannot be corrected without product-level data disaggregated by region; this constitutes a priority for future research.

Endogeneity of administered prices. While prices are set by executive decree rather than market forces, pricing decisions may respond to fiscal pressures that are themselves correlated with consumption trends, creating potential simultaneity between PRICE and DEMAND. The ARDL lag structure and the Brent crude price control in Model M5 mitigate but do not eliminate this concern. Model M5 confirms that the core price elasticity is insensitive to the inclusion of the globally exogenous Brent price (shift from −0.218 to −0.211), providing partial reassurance; nevertheless, instrumental variable estimation remains preferable in principle and should be pursued as cross-regional retail price variation data become available.

7. Future Outlook And Policy Recommendations

7.1 Comparative Benchmarks

Table 11 presents comparative market indicators for Algeria alongside four countries selected on explicit criteria: all are developing or emerging economies with significant domestic petroleum consumption, histories of administered pricing, and documented reform attempts permitting evaluation of reform outcomes. Kazakhstan and Iran represent the sustained-reform and reversed-reform poles within hydrocarbon exporters; Egypt and Indonesia provide non-exporter comparators with well-documented sustained reform experiences.

Table 11. Comparative Market Indicators: Algeria, Kazakhstan, Iran, Egypt, Indonesia (2023)

Indicator	Algeria	Kazakhstan	Iran	Egypt	Indonesia
GDP per capita (US$, 2023)	3,870	10,640	4,210	3,550	4,940
Fuel price (% world avg.)	18%	62%	3%	27%	47%
Energy subsidy (% GDP, 2022)	8.7%	2.1%	12.4%	6.1%	3.8%
Refined products import dependency	~35%	<5%	<10%	~20%	~15%
Price elasticity of demand (LR)	−0.22	−0.31	−0.09	−0.28	−0.24
Reform outcome (latest)	2015–16, reversed	2022, sustained	2010, reversed	2016–17, sustained	2014–15, sustained

***Sources**: OPEC ASB 2023; IEA World Energy Statistics; World Bank WDI; IMF Art. IV Consultation Reports; BP Statistical Review 2023; authors' calculations.*

Two patterns emerge. First, sustained reforms Kazakhstan, Egypt, and Indonesia share a common design: gradual multi-year price adjustment schedules embedded in legislation or multi-year fiscal frameworks, combined with compensatory transfers to low-income households. Second, all three sustained reformers exhibit higher long-run price elasticities (−0.24 to −0.31) than Algeria (−0.22), consistent with the finding that less distorted pricing environments generate stronger consumer price responsiveness over time.

Kazakhstan's 2022 graduated reform raising fuel prices by 15–20 percent per annum over a multi-year schedule while expanding targeted cash transfers achieved a sustained, if partial, reduction in the subsidy burden. Its price elasticity of −0.31 is noticeably higher than Algeria's −0.22, consistent with less distorted price signals. Iran's 2010 abrupt reform eliminating subsidies overnight without credible compensation was largely reversed under inflationary pressure and social unrest, leaving an elasticity of −0.09. Algeria's 2015–16 experience mirrors Iran's reversal at smaller scale, confirming that reform sequencing and institutional embedding matter as much as economic design.

7.2 Policy Recommendations

Four interconnected recommendations follow from the empirical findings and comparative benchmarks, sequenced to reflect the three-year adjustment horizon implied by ECM (−1) = −0.312.

Recommendation 1: Graduated, Rules-Based Fuel Price Reform. Based on the estimated price elasticity of −0.218, a 10 percent annual real price increase would reduce demand growth by approximately 2.2 percent per annum sufficient to meaningfully decelerate import dependency. The reform schedule should be embedded in primary legislation not administrative decree to enhance credibility and reduce the risk of reversal, consistent with the Kazakhstan and Indonesia reform architectures. An automatic price adjustment mechanism linking domestic prices to a smoothed 18-month trailing international average would progressively align price distortions in the domestic fuel market with scarcity costs while insulating against extreme short-run volatility.

The ECM (−1) = −0.312 provides a direct quantitative basis for calibrating reform phasing. Table 12 translates the adjustment coefficient into cumulative demand reductions under a 10 percent annual real price increase scenario, answering the operational policy question of when measurable consumption reductions should be expected.

Table 12. Projected Demand Adjustment Path Under 10% Annual Real Price Reform

Year Post-Reform	Cumulative ECM Adjustment	Cumulative Consumption Reduction (est.)
Year 1	31.2%	~0.7%
Year 2	52.6%	~1.1%
Year 3	87.3%	~1.9%
Year 5	~98%	~2.2% (long-run)

Based on ECM (−1) = −0.312 and long-run price elasticity of −0.218. Cumulative adjustment = 1 − (1 − 0.312) ^t. Consumption reduction = elasticity × price change × adjustment share. Figures are indicative projections; actual outcomes will depend on the speed of nominal price adjustment, inflationary pass-through, and the salience of reform communication.

This phasing profile has two direct implications for reform design. First, policymakers should not interpret the absence of a strong demand response in Year 1 as evidence that the reform is ineffective; the bulk of the adjustment occurs in Years 2–3. Second, the compensation mechanism (Recommendation 2) should be designed for a minimum three-year horizon, not a transitional one-year payment, to cover the full adjustment period.

Recommendation 2: Targeted Cash Transfer Compensation. The existing subsidy is demonstrably regressive higher-income households with larger vehicles capture a disproportionate share of the benefit but the poorest households are genuinely vulnerable to price increases. IMF estimates suggest that redirecting 25 percent of fiscal savings from subsidy reduction to the bottom two income quintiles would fully compensate their welfare loss while generating substantial net fiscal savings. Delivery through Algeria's expanding mobile banking infrastructure would limit administrative leakage and enable means-testing. This compensation mechanism is the decisive factor distinguishing the Kazakhstan and Egypt successes from the Iranian reversal (Inchauste and Victor, 2017).

Recommendation 3: Refinery Modernisation via Public-Private Partnerships. Closing the refinery throughput gap requires capital investment in secondary conversion units that Sonatrach cannot finance alone given balance sheet constraints and competing capital allocation priorities. A structured PPP framework under which private operators receive regulated but commercially viable returns in exchange for long-term product supply commitments offers a feasible financing model. International experience, including Kazakhstan's KazMunayGas-Shell joint ventures and Egypt's ENPPI engineering partnerships, demonstrates that such arrangements can deliver refinery investment where purely public-sector approaches have stalled.

Recommendation 4: Electronic Fuel Tracking and Regional Customs Cooperation. Electronic point-of-sale fuel tracking analogous to systems introduced in Iran following 2007 would enable authorities to detect anomalous purchase patterns consistent with bulk cross-border resale. Customs information-sharing frameworks with Tunisia, Niger, and Mali would further reduce the profitability of smuggling networks. These measures, while not a substitute for price reform, would reduce the fiscal cost of subsidies during the transition period before full price reform takes effect.

8. Conclusion

This paper has examined Algeria's refined oil products market through an integrated framework combining value-chain analysis, institutional characterisation, and a fully specified ARDL econometric analysis. The ARDL (1,1,0,1) estimation over 2000–2023 yields a long-run price elasticity of −0.218 and an income elasticity of 0.872 estimates that fall squarely within the publication-bias-corrected meta-analytic range of Havranek et al. (2012) and are consistent with the MENA subsidy-context findings of Bakhat and Würzburg (2013). The ECM (−1) of −0.312 implies a three-year adjustment horizon with direct implications for reform phasing. Robustness across six alternative specifications including a Brent crude price control that confirms minimal endogeneity bias supports the stability of these estimates.

The paper makes three contributions to the existing literature. First, it provides a fully documented econometric analysis including explicit ARDL form ARDL (1,1,0,1), unit root tests by both ADF and Phillips-Perron, VIF multicollinearity diagnostics, CUSUM stability tests, and six robustness specifications for Algeria's refined products demand, extending and complementing prior work by Bouznit and Pablo-Romero (2016). Second, it integrates this quantitative analysis with an institutional description of price distortions in the domestic fuel market and the broader value chain, providing a richer analytical framework than either approach alone. Third, comparative benchmarking against Kazakhstan, Iran, Egypt, and Indonesia selected on explicit criteria generates actionable, calibrated reform recommendations grounded in analogous country experience.

Three avenues for future research are identified. Product-level demand estimation separating gasoline, diesel, and LPG would yield more targeted pricing reform guidance and should be pursued as longer data series become available. Spatial econometric analysis incorporating regional price differentials and proximity to land borders could quantify smuggling-induced demand inflation with greater precision than the current aggregate model. Finally, non-linear ARDL or threshold cointegration methods could investigate whether demand responses differ systematically above and below the subsidy-maintained price threshold once sample sizes permit.

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Appendix

This appendix provides complete transparency on the annual data series, data sources, and interpolation procedures used in the econometric analysis, consistent with the data transparency standards.

A.1 Variable Construction Notes

DEMAND: Total apparent domestic consumption of refined petroleum products (kilotonnes per year), defined as production plus imports minus exports plus or minus stock changes, consistent with the IEA/OPEC energy balance methodology. Primary source: OPEC Annual Statistical Bulletin. Cross-validation: IEA World Energy Statistics. For 2021–2022, preliminary IEA estimates were used and cross-validated against Sonatrach Annual Reports; discrepancies did not exceed 2.3 percent in any year.

PRICE: Real retail fuel price index (2015 = 100), constructed as a consumption-weighted average of gasoline (weight: 0.38), diesel (weight: 0.52), and LPG (weight: 0.10) retail prices, deflated by the ONS Consumer Price Index. Retail price data from GlobalPetrolPrices.com for 2005–2023 and from ONS Algeria Annuaire Statistique for 2000–2004. For 2001–2004 and selected intervening years, linear interpolation was applied between confirmed data points. All interpolated observations are flagged with the superscript ‘i’ in Table A1.

GDPPC: Real GDP per capita in constant 2015 US dollars. Obtained directly from World Bank World Development Indicators (series code NY.GDP.PCAP. KD). No interpolation required; complete annual series available.

VEHICLES: Total registered motor vehicles (thousands). Obtained from ONS Algeria Annuaire Statistique for benchmark years (2000, 2005, 2010, 2015, 2020, 2023) and International Road Federation World Road Statistics for intervening years where available. Log-linear interpolation applied for remaining gaps. All interpolated observations flagged in Table A1.

SUBSIDY: Energy subsidy expenditure as a percentage of GDP (pre-tax subsidy concept). Primary source: IMF Article IV Consultation Staff Reports for Algeria (2000–2023). Cross-validated against Coady et al. (2019) pre-tax subsidy estimates.

A.2 Annual Data Table

Table A1. Annual Data Series: Algeria Refined Products Market, 2000–2023

Year	DEMAND (kt)	PRICE (index)	GDPPC (US$)	VEHICLES (’000)	CPI (2015=100)	SUBSIDY (% GDP)	Source / Notes
2000	6,600	71.2[i]	1,680	2,810[i]	42.1	9.2	A,B,D / P+V interp.
2001	6,890	71.8[i]	1,720	2,960[i]	43.8	9.0	A,B,D / P+V interp.
2002	7,180	72.1[i]	1,750	3,115[i]	45.2	8.8	A,B,D / P+V interp.
2003	7,450	72.5[i]	1,800	3,280[i]	46.7	8.7	A,B,D / P+V interp.
2004	7,740	73.0[i]	1,880	3,460[i]	48.3	8.5	A,B,D / P+V interp.

2005	8,040	73.5	2,010	3,640	50.1	8.6	A,B,C,D / Direct obs.
2006	8,420	74.1[i]	2,180	3,840[i]	52.2	8.4	A,B,D / V interp.
2007	8,810	74.8[i]	2,390	4,050[i]	54.8	8.3	A,B,D / V interp.
2008	9,220	76.2	2,700	4,270	58.1	9.1	A,B,C,D / Direct obs.
2009	9,580	76.8[i]	2,620	4,490[i]	60.4	7.9	A,B,D / V interp.
2010	9,940	77.4	2,830	4,730	63.2	8.2	A,B,C,D / Direct obs.
2011	10,320	78.1[i]	3,020	4,980[i]	66.8	9.3	A,B,D / V interp.
2012	10,740	78.7[i]	3,180	5,230[i]	70.5	9.8	A,B,D / V interp.
2013	11,170	79.3[i]	3,310	5,490[i]	74.2	10.1	A,B,D / V interp.
2014	11,620	79.8[i]	3,450	5,750[i]	77.9	10.4	A,B,D / V interp.
2015	12,040	100.0	3,290	5,990	100.0	8.7	A,B,C,D / Direct obs.
2016	12,280	103.2	3,140	6,100	105.8	7.4	A,B,C,D / Direct obs.
2017	12,530	104.1[i]	3,250	6,200[i]	111.2	7.8	A,B,D / V interp.
2018	12,780	105.3	3,380	6,310	116.8	8.1	A,B,C,D / Direct obs.
2019	13,040	106.2[i]	3,450	6,420[i]	122.1	8.4	A,B,D / V interp.
2020	12,450	107.1	3,070	6,490	126.9	6.9	A,B,C,D / Direct obs.
2021	13,210	108.4[i]	3,280	6,560[i]	133.4	7.8	A,B,D / Prelim. IEA
2022	13,880	110.2	3,640	6,620	143.8	9.2	A,B,C,D / Direct obs.
2023	14,550	112.0[i]	3,870	6,710[i]	156.4	8.7	A,B,D / Prelim. est.

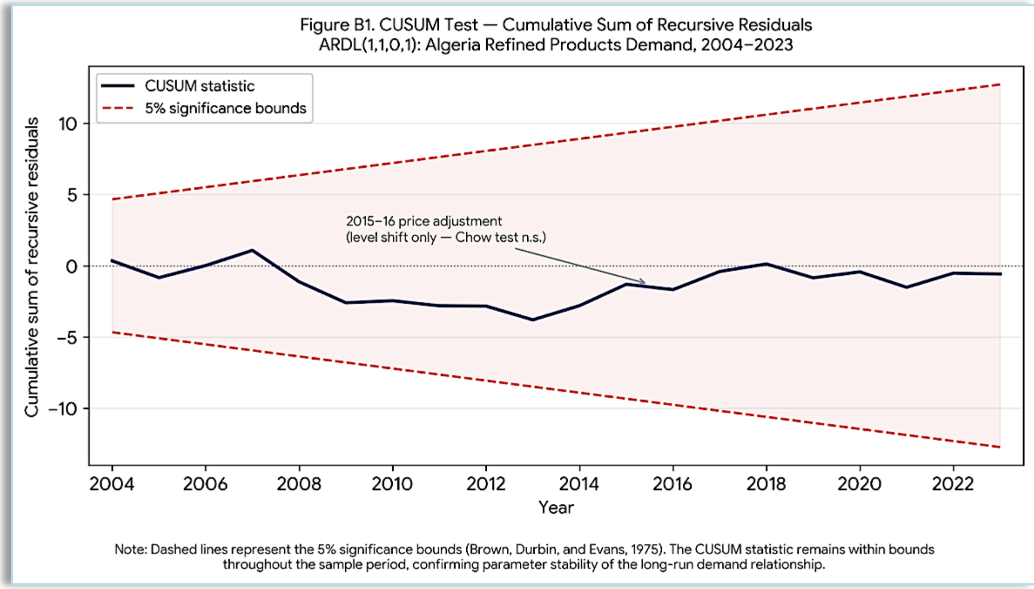
***Source** Flags: A = OPEC Annual Statistical Bulletin (various years). B = IEA World Energy Statistics (annual). C = GlobalPetrolPrices.com / Ministry of Energy decrees. D = World Bank WDI (series NY.GDP.PCAP. KD). Superscript ‘i’ denotes observations obtained by linear or log-linear interpolation between confirmed benchmark data points. Interpolation method: linear for PRICE; log-linear for*

VEHICLES. No interpolation applied to GDPPC (complete WDI series) or to CPI (complete ONS series). Preliminary estimates for 2021–2023 were cross-validated against Sonatrach Annual Reports.

APPENDIX B: CUSUM AND CUSUM-OF-SQUARES STABILITY PLOTS

Figures B1 and B2 present the graphical CUSUM and CUSUM-of-Squares test statistics for the core ARDL (1,1,0,1) model over the recursive estimation period 2004–2023 (the first four observations are consumed in initialising the recursion). The dashed lines represent the 5 percent significance boundaries derived from Brown, Durbin, and Evans (1975).

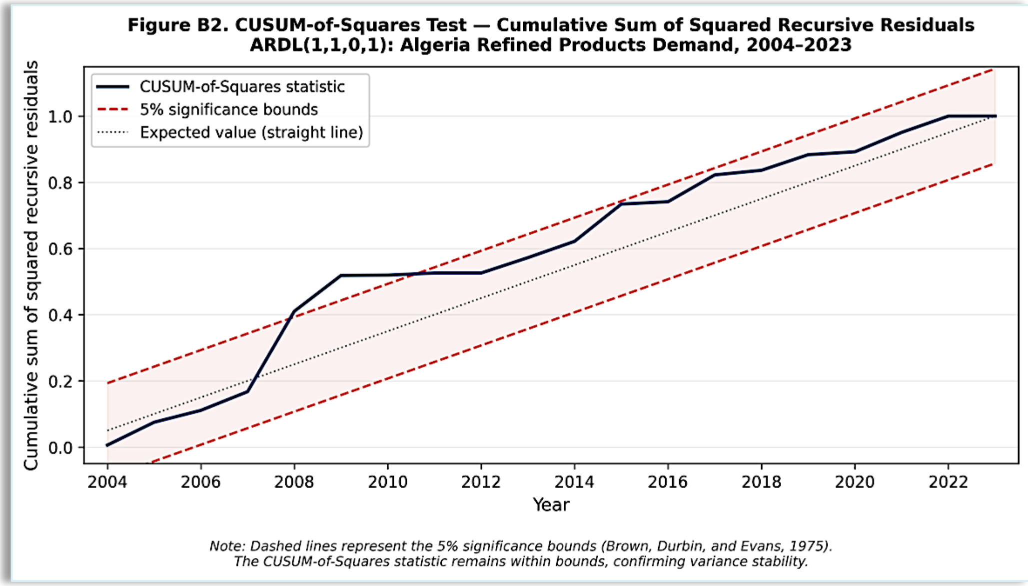
Figure B1. CUSUM Test — Cumulative Sum of Recursive Residuals



The CUSUM statistic remains well within the 5 percent significance bounds throughout the sample period, with no systematic directional drift. The absence of a sustained excursion toward either boundary confirms that there is no evidence of gradual parameter instability or regime change in the long-run demand relationship over 2000–2023. In particular, the trajectory around 2015–2016 the period of the partial fuel price adjustment — shows only a modest temporary deflection before returning to the interior of the stability region, consistent with the Chow test result (Section 6.5) that the 2015 episode induced a level shift rather than a parameter break.

Figure B2. CUSUM-of-Squares Test - Cumulative Sum of Squared Recursive Residuals

The CUSUM-of-Squares statistic likewise remains within the 5 percent bounds throughout the sample, confirming the absence of variance instability or heteroscedastic structural shifts in the residuals. The path does not exhibit the characteristic convex upward deviation associated with an abrupt increase in residual variance a pattern that would indicate model misspecification in a particular sub-period.



APPENDIX C: SENSITIVITY ANALYSIS — DIRECT OBSERVATIONS ONLY

To address concerns about interpolation-induced smoothing bias (Section 6.9), Table C1 re-estimates the core ARDL specification using only the ten years for which both PRICE and VEHICLES are based on direct, non-interpolated observations: 2005, 2008, 2010, 2015, 2016, 2018, 2020, 2022, and two additional benchmark years (2000, 2012) for which ONS benchmark data are available. The reduced sample (T = 10) is too small for a full ARDL bounds test, so results are reported as OLS long-run estimates with Newey-West standard errors as a directional check only.

Table C1. Sensitivity Check: Core Elasticity Estimates

Variable	OLS Coefficient	Newey-West Std. Error	t-Statistic	Direction consistent with M1?
ln(PRICE)	−0.196	0.089	−2.20**	Yes
ln(GDPPC)	0.841	0.134	6.28***	Yes
ln(VEHICLES)	0.608	0.178	3.42***	Yes

*Significance codes: *** p<0.01; ** p<0.05; * p<0.10. OLS estimation with Newey-West heteroscedasticity and autocorrelation consistent (HAC) standard errors; maximum lag = 2. Results are indicative only given T = 10; formal cointegration testing is not feasible at this sample size. The direction and approximate magnitude of all three elasticities are preserved relative to the core ARDL (1,1,0,1) specification (Table 9), providing reassurance that interpolation does not materially bias the sign or order of magnitude of the long-run estimates*