Czech University of Life Sciences Prague

Faculty of Economics and Management

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Bachelor Thesis

The Impact of Renewable Energy on Fuel Import Dependence: A Case Study of Czech Republic

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

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Business Administration

Thesis title

The Impact of Renewable Energy on Fuel Import Dependence: A Case Study of Czech Republic

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Objectives of thesis

1- To examine the impact of renewable energy consumption on fuel import dependence in Czechia.

2- To assess the role of GDP growth rate, crude oil prices, and trade openness on fuel import dependence.

3- To provide policymakers with insights on the relationship between renewable energy consumption and fuel import dependence in Czechia.

Methodology

The study will utilize secondary data spanning from 2001 to 2021 for Czech Republic.. The dependent variable is fuel imports, measured as a percentage of merchandise imports, which will be sourced from World Bank database. The primary independent variable, renewable energy consumption (measured as a percentage of total final energy consumption), will be obtained from World Bank database. Additionally, the study will include three controlled variables: GDP growth rate, crude oil prices, and trade openness, all will be obtained from international databases such as the World Bank and Statista.

To analyze the impact of renewable energy consumption on fuel import dependence, a multiple linear regression model will be employed. The model will aim to isolate the effect of renewable energy consumption while controlling for GDP growth rate, crude oil prices, and trade openness. The general model will take the form: Fuel import=β0+β1Renewable Energy Consumption+β2GDP Growth Rate+β3Crude Oil Price+β4 Trade Openness+Ɛ

Where:

Fuel import: The dependent variable, representing the proportion of total imports that consist of fuel products.

β0: The intercept term, capturing the baseline level of fuel imports when all independent variables are zero.

β1: The coefficient for renewable energy consumption (% of total final energy consumption), measuring the impact of renewable energy usage on fuel imports.

β2: The coefficient for GDP growth rate, controlling for the influence of economic growth on fuel imports.

β3: The coefficient for crude oil prices, accounting for how changes in global oil prices affect fuel import levels.

β4: The coefficient for trade openness (% of GDP), controlling for the degree of openness of the economy to international trade and its effect on fuel imports.

Ɛ: The error term, representing other factors affecting fuel imports not included in the model.

Diagnostic tests, such as multicollinearity and heteroscedasticity tests, will be conducted to ensure the model's validity and robustness. Key performance indicators like R-squared and p-values will be used to interpret the results.

The results will provide insights into how renewable energy consumption impacts fuel import dependence, and whether traditional economic factors like crude oil prices and trade openness play a stronger role in this dynamic. All analysis will be conducted using Gretl statistical software.

The proposed extent of the thesis

45-50

Keywords

Renewable Energy, Fuel Import, GDP, Crude oil price, Trade Openness, Czech Republic.

Recommended information sources

Fikru M, Kilinc-Ata N. 2024. Do Mineral Imports Increase In Response To Decarbonization Indicators Other Than Renewable Energy?. Journal of Cleaner Production 435: e140468.

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Statista Research Department. 2024. Crude oil price index worldwide from 1991 to 2023. Available at: https://www.statista.com/statistics/1303218/crude-oil-price-index-worldwide/. Accessed: September 19, 2024.

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Expected date of thesis defence

2024/25 SS – PEF

Thesis supervisor

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Dean

Prague on 30. 11. 2025

Declaration

I declare that I have worked on my bachelor thesis titled "The Impact of Renewable Energy on Fuel Import Dependence: A Case Study of Czech Republic" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 30.11.2025 ______________________________

Acknowledgement

I would like to thank Ing. Ghaeth Fandi, Ph.D. and Ing. Safwan Ghanem for their advice and support during my work on this thesis. I would also like to express my gratitude to all my loved ones for their support throughout my studies.

The Impact of Renewable Energy on Fuel Import Dependence: A Case Study of Czech Republic

ABSTRACT

This study analyzes how renewable energy deployment shapes fuel import share in the Czech Republic over the study period 2000–2021. The empirical strategy uses an ordinary least squares (OLS) specification with fuel import share as the dependent variable and renewable energy deployment, real output growth, world oil prices, and trade openness as regressors. This model is supported by standard specifications and diagnostic tests, which demonstrate that the model is statistically robust and its results can be reliably validated. The results indicate a stable and economically significant negative association between renewable energy deployment and fuel import share. While the estimated effects of output growth, oil prices, and openness are statistically weak in this context, renewables displace imported fossil fuels in power, heating, and mobility. Efficiency improvements, sectoral restructuring, financial and contractual arrangements, and technology diffusion dampen demand and mitigate the price transmission to the import share measure. Trade openness provides compensating channels, as the benefits of diversification are balanced by exposure to external shocks, helping to explain the muted overall effect, Policy should prioritize incremental renewable additions in heating and transmission, and link new capacity with interconnections in storage and demand response to translate nominal capacity into reliable import displacement and stronger energy security.

Keywords: Renewable energy, fuel import share, Czechia, energy security, OLS

Dopad obnovitelných zdrojů energie na závislost na dovozu paliv: Případová studie České republiky

ABSTRAKT

Tato studie analyzuje, jak zavádění obnovitelných zdrojů energie ovlivňuje podíl dovozu paliv v České republice ve sledovaném období 2000–2021. Empirická strategie využívá specifikaci obyčejných nejmenších čtverců (OLS) s podílem dovozu paliv jako závislou proměnnou a zaváděním obnovitelných zdrojů energie, růstem reálné produkce, světovými cenami ropy a otevřeností obchodu jako regresními faktory. Tento model je podpořen standardními specifikacemi a diagnostickými testy, které prokazují, že model je statisticky robustní a jeho výsledky lze spolehlivě validovat. Výsledky naznačují stabilní a ekonomicky významnou negativní souvislost mezi zaváděním obnovitelných zdrojů energie a podílem dovozu paliv. Zatímco odhadované účinky růstu produkce, cen ropy a otevřenosti jsou v tomto kontextu statisticky slabé, obnovitelné zdroje energie nahrazují dovážená fosilní paliva v elektřině, vytápění a mobilitě. Zlepšení efektivity, restrukturalizace odvětví, finanční a smluvní ujednání a difúze technologií tlumí poptávku a zmírňují přenos cen do míry podílu dovozu. Otevřenost obchodu poskytuje kompenzační kanály, protože výhody diverzifikace jsou vyváženy vystavením se vnějším šokům, což pomáhá vysvětlit tlumený celkový efekt. Politika by měla upřednostňovat postupné zvyšování kapacity z obnovitelných zdrojů v oblasti vytápění a přenosu a propojovat novou kapacitu s propojením v oblasti skladování a reakce na poptávku, aby se nominální kapacita proměnila ve spolehlivé nahrazení dovozu a silnější energetickou bezpečnost.

Klíčová slova: Obnovitelná energie, podíl dovozu paliv, Česko, energetická bezpečnost, OLS

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1-Introduction:

Energy security and trade exposure shape macroeconomic stability in small open economies. Countries that rely on imported fossil fuels face price shocks, balance-of-payments pressure, and policy constraints. Expanding renewable energy can lower exposure by displacing imported fuels and smoothing external accounts. This study examines whether higher renewable energy consumption reduces fuel import dependence in the Czech Republic. It frames fuel imports as a share of merchandise imports and evaluates the role of growth, global oil prices, and trade openness as controls. The goal is empirical and policy-relevant. It tests if renewables act as a hedge against external energy risk for a mid-sized EU economy.

Recent work connects the green transition to import dependence and market risk. European studies link energy security to new policy frames and supply diversification (LaBelle, 2024; Sterling, 2025; Kim et al., 2025). Trade-focused analyses show shifting import dependencies during the transition and the role of EU integration (Li and Song, 2025; Eschmann and Jochem, 2025; Lekavičius et al., 2024). Research on the energy–growth nexus and trade channels supports controlling for macro conditions when estimating import shares (Jóźwik et al., 2024; Ilechukwu and Lahiri, 2022). Oil price pass-through and volatility explain part of the external constraint faced by importers, which motivates explicit oil price controls in the model (Deltas, 2024; Gago and Vale, 2025). Case and regional evidence suggests renewables can substitute for imported fuels under credible policy and grid integration (Overland et al., 2022; Hong, 2022; Pavlík, 2025). These strands guide the variable set and identification strategy used here.

The research is organized as follows. The next section states the objectives and describes the data sources and variables, including renewable energy consumption, fuel imports, GDP growth, global oil prices, and trade openness. It explains the empirical strategy and diagnostics to assess model validity The following section reviews the relevant literature to position the contribution against EU-focused and trade-oriented studies The empirical section presents descriptive statistics, correlations, model estimates and robustness checks The final section discusses results for policy and outlines practical implications for reducing import dependence through the renewable mix, followed by conclusions and references.

2-Objectives and Methodology

2.1 Objectives

The objectives focus on testing whether higher renewable energy consumption lowers dependence on imported fossil fuels in the Czech Republic. The analysis treats fuel imports as a share of merchandise imports and embeds macro and external controls, The aim is to produce precise evidence that can guide energy and trade policy:

- Quantify the effect of renewable energy consumption on the fuel-import share while controlling for GDP growth, global oil prices, and trade openness.
- Probe mechanisms by estimating interactions between renewables and oil prices and between renewables and trade openness.
- Distinguish short-run and long-run effects and evaluate responses external shocks.
- Test robustness across, alternative variable definitions, model specifications and sample splits and address endogeneity using instrumental or lagged variables.

2.2 Methodology

This study adopts a transparent empirical strategy based on annual country data for Czechia from 2001 to 2021, The period 2000–2021 was selected because it covers the entire modern energy transition cycle before the 2022 Russia-Ukraine war shock, including the post-2000 renewable energy adoption wave, EU accession in 2004, the 2003–2014 oil supercycle, the 2008–2009 financial crisis, the 2014–2016 oil price collapse, and the 2020–2021 pandemic and recovery shocks. It also ensures consistent availability of World Bank indicators, as some are not available after 2021. and estimates a parsimonious linear model that links the share of fuel imports in total merchandise imports to renewable energy consumption and standard macro controls using ordinary least squares in Gretl; OLS was chosen because it estimates the average conditional effect with high transparency and interpretability when variables are measured as ratios and growth rates, reducing the risk of non-stationarity, and because diagnostic tests on the similar annual sample showed good linear fit and the absence of first-order autocorrelation, the baseline specification is:

$$FIM_t = \beta_t + \beta_1 REC_t + \beta_2 GDP_t + \beta_3 COP_t + \beta_4 TOP_t + \varepsilon_t$$

where FIM_t is fuel imports as a percentage of merchandise imports that captures external energy exposure,

REC_t is renewable energy consumption as a percentage of total final energy consumption that proxies the domestic substitution margin with an expected negative sign for β_1,

GDP_t is real GDP growth in percent that controls for demand pressure and business cycle effects, COP_t is the Brent crude oil price in US dollars per barrel that captures external price shocks with an expected positive sign for β_3,

TOP_t is trade openness measured as trade in goods and services as a percentage of GDP that captures structural exposure to international markets; data assembly and cleaning precede estimation, then descriptive statistics and pairwise correlations establish scale, variation, and bivariate associations, after which the model is estimated and validated through a sequence of diagnostic tests that include residual normality checks, White's test for heteroskedasticity, Breusch–Godfrey for serial correlation, Ramsey RESET for functional-form adequacy, Belsley–Kuh–Welsch collinearity diagnostics, and CUSUMSQ for parameter stability, and we report standard fit metrics to document explanatory power and joint significance; robustness work extends the baseline by exploring interactions between REC and COP to test whether renewables dampen oil price pass-through, interactions between REC and TOP to assess whether openness conditions the substitution effect, alternative variable definitions and sample splits to probe sensitivity, and a simple endogeneity probe that instruments REC with its lag to mitigate reverse causality concerns, while levels in shares and growth rates reduce unit root risk in small T; all variables are defined in percent except COP which is in US dollars per barrel, all series are annual and country specific, and all computations use consistent sample coverage to avoid listwise deletion, which supports comparability across specifications and diagnostics.

3-Literature Review

The recent European literature reframes energy security around sovereignty, resilience, and solidarity, and links these pillars to the pace and composition of the green transition rather than to simple import volumes alone (LaBelle, 2024) Empirical monitors still show high and uneven energy import dependence across EU members, which motivates country studies that isolate drivers of exposure and the role of domestic renewables in offsetting it (Sterling, 2025; Eurostat, 2024, 2025). Structural-gravity evidence finds that the transition reshapes import dependencies through trade reconfiguration, technology sourcing, and policy alignment, reinforcing the need to treat openness and market integration as core controls when explaining fuel-import shares (Eschmann and Jochem, 2025). Diversification studies add that EU members reduce vulnerability when they broaden both energy resources and equipment suppliers, which makes import exposure a function of portfolio breadth as well as volumes (Lekavičius et al., 2024) A key mechanism is spatial availability Renewables exhibit a more even geographic distribution than fossil fuels, which can temper geopolitical concentration risk and lower the probability of sharp import shocks for mid-sized economies like Czechia (Overland et al., 2022) Country-comparative work on sustainable energy trajectories in Central Europe underscores heterogeneous baselines and policy capacities, supporting a country-specific identification strategy for Czechia that recognizes regional commonalities but allows local dynamics to dominate the estimates (Żak and Pyra, 2024) .

Macroeconomic and trade channels shape import needs and their sensitivity to external prices EU-wide panel and causality studies show that energy use and output co-move, with growth phases raising demand and tightening energy balances, which justifies including GDP growth as a demand-pressure control (Jóźwik et al., 2024; Perera et al., 2024) Oil price transmission work documents incomplete and state-dependent pass-through from crude costs to retail fuel prices, implying that global oil benchmarks enter as an exogenous shock that conditions import values rather than only volumes (Deltas, 2024) Broader inflation studies confirm that oil shocks propagate into CPI and PPI amplifying the external constraint faced by import-dependent economies and validating explicit oil-price controls in import-share regressions (Gago and Vale, 2025) Using long crude price histories helps quantify these shocks consistently across years which strengthens identification relative to short windows of volatility (Statista, 2024) Trade research further shows that renewable-energy deployment interacts with international trade in both directions Openness can speed diffusion of clean technologies and inputs, yet it can also import exposure to price cycles and supply bottlenecks warranting the inclusion of trade openness both as a confounder and as an interaction with renewables (Ilechukwu and Lahiri, 2022).

Evidence that renewables curb fossil-fuel imports accumulates across case and regional analyses though magnitudes vary with policy credibility grid integration, and technology mix. A country study finds that ramping renewable production reduces fossil-import demand, especially where capacity additions target peak-load displacement and heating fuels, which supports a substitution mechanism testable in single-country models (Hong, 2022) Work on electricity price dynamics suggests that higher renewable penetration stabilizes wholesale prices in several European markets, consistent with dampened exposure to imported fuels and with weaker pass-through from global oil shocks into domestic energy costs (Pavlík, 2025) Strategy studies argue that an optimal renewable mix can raise energy security by aligning resource profiles with system needs and by reducing import intensity of the energy bundle, a claim that invites interaction tests between renewables and external price shocks as well as openness (Osuma and Yusuf, 2025) The transition also shifts dependencies toward critical minerals and equipment, so any measured decline in fuel-import shares must be interpreted alongside potential increases in upstream green-supply imports, particularly in minerals, components, and balance-of-system parts (Fikru and Kilinc-Ata, 2024).

Together, these studies justify a baseline in which fuel imports as a share of merchandise imports respond negatively to renewable energy consumption, positively to global oil prices, and variably to growth and openness, with data definitions aligned to widely used World Bank indicators to ensure comparability and replication.

This study adds four things the literature has not combined in one place for Czechia across 2001–2021. First, it shifts the outcome from energy use or prices to a policy-salient ratio, fuel imports as a share of merchandise imports, which captures the external constraint faced by trade and fiscal planners. Second, it embeds renewables in a clear mechanism test by interacting renewable energy consumption with Brent crude prices and with trade openness to ask whether domestic clean capacity dampens global oil pass-through and whether market integration conditions that effect. Third, it treats identification and validation as first-order tasks for a short annual series by running a full diagnostic suite, reporting stability checks, and probing endogeneity with a simple instrument based on the lag of renewables, which most single-country studies omit. Fourth, it translates estimates into elasticities and marginal effects that answer a practical question you can use, how much additional renewable share offsets a 10-dollar oil shock at current openness and growth. Together these choices connect energy security, macro demand, and trade channels in one coherent time-series design, deliver results that travel to policy, and keep transparency high through reproducible definitions and consistent sample coverage.

3.1 Renewable energy economics and energy security

Section 3.1 frames how renewable energy economics links to energy security in a measurable way Renewable economics studies costs, learning curves, risk, and policy incentives that shape investment and dispatch.

Energy security concerns adequacy, reliability, affordability, and resilience under shocks. Both fields meet in the choice of the energy mix and in how fast systems can reallocate supply when prices move or trade is disrupted. The relevant metrics include import dependence, supplier concentration, exposure to global benchmarks, reserve margins, and system flexibility through storage, transmission, and demand response. Renewables change these metrics by replacing fuel inputs with capital, by reducing marginal cost volatility, and by shifting exposure from traded fuels to domestic resources and equipment. The net effect depends on integration costs, grid flexibility, policy credibility, and technology mix. It also depends on trade openness and growth that raise or dampen import needs. Our analysis uses fuel imports as a share of merchandise imports as the exposure metric and renewable energy consumption as the key driver. The next subsection sets out the energy substitution hypothesis that organizes this link.

3.1.1 Energy substitution hypothesis

The energy substitution hypothesis states that renewable deployment replaces fossil fuels across electricity, heating, and transport, Wind solar, and hydro displace coal and gas in power generation Heat pumps biomass, and district heating cut oil and gas use in buildings Electric vehicles and advanced biofuels reduce gasoline and diesel demand As the renewable share rises the economy needs fewer fossil fuel inputs and fewer imported fuel barrels. This mechanism links renewable economics directly to energy security through lower import needs (European Environment Agency, 2025; Kim et al., 2025; Hong, 2022).

The transmission runs through two connected channels. First, physical substitution lowers volumes of imported fuels used for power, heat, and mobility. Second, reduced fuel burning weakens exposure to international benchmarks and price pass-through into domestic energy costs. Lower exposure also dampens volatility in wholesale electricity and end user prices. At the trade account level, these shifts show up as a smaller fuel line within merchandise imports. The share falls when imported fuel volumes drop faster than other imports of goods and services. This path is consistent with evidence on pass-through, price stabilization with renewables, and observed import dependency patterns in Europe (Deltas, 2024; Pavlík, 2025; Eurostat, 2024).

The testable prediction is clear. Renewable energy consumption should be negatively associated with dependence on fuel imports once we hold output growth, oil prices, and trade openness constant. The expected sign on the renewable variable in the import-share equation is negative. Substitution in electricity, heating, and transport is the mechanism behind this coefficient. Trade oriented studies and country evidence during the transition support this sign and the relevance of controls that capture reconfigured import dependencies and market integration (Eschmann and Jochem, 2025; Ilechukwu and Lahiri, 2022; Hong, 2022).

3.1.2 Energy security and import dependence

Import dependence means meeting domestic energy needs with foreign supplies and being exposed to price shocks and supply volatility. In Europe, this exposure varies by country and fuel and creates macro risks when global benchmarks move. Oil shocks pass through to retail energy and to CPI and PPI, which tightens the external and policy constraint for importers. Measured indicators such as Eurostat's energy import dependency and trade-based shares document this risk and its fluctuations through recent crises. These facts justify modeling price shocks and supply variability as first-order drivers of external exposure. (Eurostat, 2024, 2025; Kim et al., 2025; Sterling, 2025; Gago and Vale, 2025; Deltas, 2024).

Diversification, efficiency, and pricing policy reduce external exposure by different channels.

Diversifying energy resources and equipment suppliers lowers concentration risk and smooths trade shocks. Efficiency measures cut fuel intensity so fewer imported units are needed at any level of activity. Plausible pricing that offers costs and accommodates flexibility enhances the substitution and demand response in case of a global shift in prices. The issue of openness and trade integration is not redundant and thus the policies have to be coupled with diversification and efficiency combined with market design that would favor competition and flexibility in imports where necessary. These levers are validated by European studies with the transition and reveal that countries whose portfolios are broader and demand side gains are low in terms of vulnerability. (Lekavičius et al., 2024; LaBelle, 2024; Ilechukwu and Lahiri, 2022; Osuma and Yusuf, 2025; Bąk et al., 2025).

Growth in renewables raises energy security and lowers import dependence through fossil substitution in power, heat, and transport and by dampening exposure to imported fuel prices. Evidence shows that higher renewable penetration displaces coal, oil, and gas use, stabilizes wholesale electricity prices, and reconfigures import links during the transition. The expected sign between renewable consumption and fuel import dependence is negative once we control for growth, oil prices, and openness, and standard indicators allow consistent measurement across years and countries. This mechanism aligns with European and country studies and with monitoring by EU and international sources. (European Environment Agency, 2025; Hong, 2022; Pavlík, 2025; Eschmann and Jochem, 2025; World Bank, 2025b, 2025c; Eurostat, 2024).

3.2 Macroeconomic and trade determinants of fuel imports

Section 3.2 explains how macroeconomic conditions and trade structure drive fuel import needs and bills. Fuel imports respond to the business cycle, external energy prices, exchange rates, and openness. When output expands, transport, industry, and households use more energy. Dollar-denominated oil and gas prices move import values even when volumes are stable. The exchange rate passes through to local currency costs and margins. Trade openness raises exposure to foreign inputs but also improves access to substitutes and suppliers. Sector mix matters because energy intensity differs across manufacturing, services, and construction. Efficiency gains and new technology can weaken the link between growth and fuel demand. Inventory management and storage policy smooth near-term import volumes. Domestic pricing and subsidy regimes steer substitution including shifts toward renewables Infrastructure and logistics set import capacity and transaction costs, These forces set the stage for the next subsections, which quantify the growth channel and its interactions with prices and openness.

3.2.1 GDP growth and energy demand

Energy demand is a derived demand from economic activity. When GDP expands, industry, transport, and households raise energy use to support higher output and mobility. Empirical work for EU economies and recent causality studies confirm a tight co-movement between energy consumption and GDP during the transition period. This justifies treating GDP growth as a primary driver of short-run energy use in small open economies. (Jóźwik et al., 2024; Perera et al., 2024; Zhai et al., 2024).

Income elasticity makes the mechanism explicit. With installed capital and habits largely fixed in the short run, higher income raises energy services and fuels in proportion to activity. Short-run elasticities are positive, even where efficiency policies and structural change weaken long-run intensity. Evidence from EU panels and time-series causality supports a positive output–energy link at business-cycle frequencies, which the model captures by including GDP growth as a control. (Perera et al., 2024; Jóźwik et al., 2024).

The expected sign for GDP growth in the fuel-import equation is therefore positive in the short run. More activity lifts fuel needs faster than domestic supply or substitution can adjust, so import requirements—and the fuel-import share in merchandise imports—tend to rise when output accelerates, conditional on oil prices and openness. Trade-focused studies on Europe and official monitors of import dependency and fuel-import shares motivate this prediction and provide consistent measures for testing it (Li and Song, 2025; Sterling, 2025; Eurostat, 2024; World Bank, 2025b).

3.2.2 Global oil prices and trade openness

Global oil prices shape the import bill through price pass-through and the terms of trade, Because crude and refined fuels are priced in dollars, a rise in benchmark prices lifts CIF values even if volumes are unchanged, and exchange-rate moves can amplify the local-currency effect. Micro and macro evidence for Europe shows incomplete but material pass-through from crude costs into retail energy prices and broader inflation, so higher oil prices raise the value of energy imports and tighten the external constraint faced by importers. Using long price series helps quantify these shocks consistently across years. (Deltas, 2024; Gago and Vale, 2025; World Bank, 2025a; Statista, 2024).

Higher oil prices can reduce imported fuel volumes at the margin but still increase the import bill, so the share of fuel imports in total merchandise imports often rises when oil prices climb, especially if non-fuel imports do not expand at the same pace, EU monitors and trade-focused studies document periods where energy import dependency and trade exposure move with global oil cycles, reinforcing the case for including oil prices as a core control in import-share models. Terms-of-trade work also links tighter environmental rules and trade dynamics to persistent oil dependence, which can magnify price-cycle effects on the import share. (Eurostat, 2024; Sterling, 2025; Li and Song, 2025; Cappelli and Carnazza, 2025).

Trade openness increases cross-border flows of goods and inputs and can raise reliance on imported fuels used for transport, industry, and electricity generation. Open economies benefit from access to diverse suppliers, but they also transmit global price movements more quickly into domestic energy costs and import values. The expected sign for openness in the fuel-import share equation is therefore positive in the short run, conditional on output and oil prices, a prediction consistent with studies that connect openness to energy trade links and with structural-gravity evidence on reconfigured import dependencies during the transition. (Lojanica, 2025; Ilechukwu and Lahiri, 2022; Eschmann and Jochem, 2025; World Bank, 2025d).

3.3 The causal link between renewable energy consumption and dependence on fuel imports

Section 3.3 asks whether higher renewable energy consumption causally reduces dependence on fuel imports rather than only moving with it. The claim is that renewables displace fossil inputs in power, heat, and transport and that this lowers imported fuel needs and the fuel import share in merchandise imports. Threats to identification include reverse causality from import shocks to renewable policy, omitted variables such as efficiency gains and sector mix, and measurement limits in short annual series. The strategy controls for GDP growth, Brent oil prices, and trade openness, exploits oil price movements through interactions to separate substitution from valuation effects, instruments renewable consumption with its lag to mitigate feedback, and applies stability, serial correlation, heteroskedasticity, and functional form diagnostics, Robustness checks vary sample windows and variable definitions and report elasticities and marginal effects to gauge economic size. The expected partial effect is negative in the short run once macro and trade drivers are held constant. The next subsection details the channels and transmission mechanisms that link renewable deployment to external exposure.

3.3.1 Channels of influence and transmission mechanisms

Renewables reduce enter imports fuels by direct replacement in three end uses. Wind, solar, and hydro would substitute coal and gas in the marginal and reduce burn rates in thermal plants. Gas and diesel in space heating and water heating are substituted by heat pumps, biomass and efficient district heating in buildings. Battery electric vehicles and sustainable biofuels are used in transport reducing the use of gasoline and diesel. The evidence in the country and the EU associates an increase in renewables penetration with a reduction in fossil inputs and a decrease in fluctuation in wholesale electricity prices, which justifies the path of substitution in both volumes and in volatility exposure. (European Environment Agency, 2025; Hong, 2022; Pavlík, 2025; Osuma and Yusuf, 2025)

Efficiency gains accompany this shift and compress total fuel needs. Variable renewables replace fuel with capital and digital control, which raises system efficiency and reduces losses in generation, heating, and mobility. Diversification of resources and suppliers further lowers concentration risk, while trade reconfiguration during the transition alters where inputs come from and how quickly shocks transmit. These channels work together to reduce the imported share of energy needs when renewable consumption rises, conditional on macro controls. (LaBelle, 2024; Lekavičius et al., 2024; Eschmann and Jochem, 2025; Ilechukwu and Lahiri, 2022).

Price and carbon elasticities govern the speed and size of import declines. When global oil prices rise, pass-through lifts the value of fuel imports even if quantities fall, so the fuel-import share can increase on the price side while volumes decline on the quantity side. The net effect on the import-share metric reflects the tug of these two forces. With renewables rising, the quantity effect intensifies and the price exposure weakens, producing the testable prediction of a negative partial correlation between renewable consumption and dependence on fuel imports after controlling for GDP growth, oil prices, and openness. Standard monitors and long price series allow consistent measurement of the value and volume components. (Deltas, 2024; Gago and Vale, 2025; World Bank, 2025a; Eurostat, 2024).

3.3.2 Modifying factors and dynamic properties

Time horizon shapes the effect. In the short run, capital and habits limit substitution. The impact is modest. Over time, new investments accumulate. Learning curves cut costs. Grid integration improves. The renewable share rises and displaces more fossil inputs. The impact of the margin on import dependence grows more strongly with accumulation of capacity, storage and flexibility and with internalization of low variable costs by the markets. The European monitoring and market studies have found evidence on increased security gains with increased renewable penetration (LaBelle, 2024; European Environment Agency, 2025; Pavlík, 2025).

Timing is regulated by the system constraints. There are restricted transmission, feeble interconnection and minimal storage that postpones transmission of renewable expansion into reduced import requirement. Early gains are drowned in censure and balancing costs. Diversifying resources and suppliers, expanding cross-border links, and upgrading flexibility reduce these frictions and stabilize the transition path. Trade reconfiguration during the transition also shifts where inputs come from and how quickly shocks transmit. These conditions set the dynamic profile of the import response. (LaBelle, 2024; Lekavičius et al., 2024; Eschmann and Jochem, 2025).

External prices, structure, and policy amplify or dampen the effect. High oil and gas prices raise the value of fuel imports and speed substitution, so the renewable impact strengthens when global prices are elevated. Trade openness and a heavy-industry mix can raise fuel needs and transmit price cycles faster, which offsets some gains unless efficiency improves. Supportive policies raise substitution elasticities. Carbon pricing, targeted investment support, and contracts for difference align incentives, lower risk, and pull forward capacity that reduces import dependence. Empirical work on pass-through, European security strategy, and transition policy corroborates these dynamics. (Deltas, 2024; Gago and Vale, 2025; Ilechukwu and Lahiri, 2022; Osuma and Yusuf, 2025; LaBelle, 2024; World Bank, 2025a).

Drawing on the theory, we take three positions that guide the empirical work. Renewable energy reduces dependence on fuel imports through substitution in power, heating, and transport, reinforced by efficiency. GDP growth raises short-run energy use and can lift import needs. Global oil prices and trade openness shape the import bill and the speed of transmission. Network limits, storage, interconnection, industry mix, and policy support modify these effects over time. I therefore expect a negative partial effect of renewable energy consumption on the fuel-import share, a positive short-run effect of GDP growth, a positive valuation effect from oil prices, and a positive effect of openness. I also expect interactions that matter for policy. Renewables should mute the oil price effect. Openness can condition substitution. These claims are testable with annual data for Czechia using standard indicators for fuel imports, renewable consumption, growth, oil prices, and openness, with diagnostics and robustness checks to verify identification and stability.

4-Practical Part

Section 4 implements the model on annual data for Czechia from 2001 to 2021. Variables were constructed, the sample was aligned, and consistent coverage was maintained across steps. Summary patterns were reported, the baseline was estimated, assumptions were tested, endogeneity was probed, and robustness checks were executed. Effect sizes were presented as elasticities and marginal effects for policy use. This is done through the following steps:

- Statistical descriptors were prepared. Mean, standard deviation, minimum, maximum, skewness, and kurtosis were computed for each variable. Time plots were inspected to detect shifts, breaks, and outliers. Units and scales were verified to maintain correct interpretations.
- Bivariate correlations were examined. Pearson coefficients were calculated among the fuel-import share, renewable consumption, GDP growth, oil prices, and openness. Signs and magnitudes were interpreted with caution because bivariate correlations ignore confounders. The matrix was used to flag collinearity risks before estimation.

- Ordinary least squares were applied with the fuel-import share as the dependent variable and renewable consumption, GDP growth, Brent oil prices, and trade openness as regressors. Coefficients were interpreted as partial conditional effects on the other controls. Robust standard errors were used for inference. Percentage variables were translated into elasticities when appropriate.
- Renewable consumption was interacted with oil prices to test the attenuation of price pass-through. Renewable consumption was interacted with openness to test whether market integration substitution conditions. Marginal effects were computed over observed values of oil prices and openness and plotted for interpretation.
- The research tested heteroskedasticity. White's test was run to detect heteroskedasticity. If detected, heteroskedasticity—robust standard errors—were retained for OLS and IV results. Variance patterns were discussed as potential scale effects or omitted interactions.
- The research tested serial correlation. The Breusch–Godfrey test was used to detect autocorrelation in residuals. When present, Newey–West heteroskedasticity and autocorrelation—consistent standard errors—were reported. Core inferences were checked for stability under HAC adjustments.
- The research tested the fit of the functional form. The Ramsey RESET test was applied to detect omitted nonlinearities or interactions. Log specifications or refined interactions were considered if RESET indicated misspecification. The most transparent specification that passed core checks was retained.
- The research examined the nature of the residuals. The Jarque–Bera test used. Normality was treated as a small-sample diagnostic rather than a consistency condition. Robust standard errors were emphasized when residuals were skewed or heavy-tailed.

The following table includes the variables used in the study and their coding:

Table 1 Variable, unit of measure, and notation

Variable	Unit of Measurement	Code
Fuel imports (% of merchandise imports)	Percentage (%)	FIM
Renewable energy consumption (% of total final energy consumption)	Percentage (%)	REC
GDP growth (annual %)	Percentage (%)	GDP
Crude Oil Prices – Dollars per Barrel	US Dollars per barrel (US$/bbl)	COP
Trade Openness (% of GDP)	Percentage (%)	TOP

Source: Prepared by the researcher based on Gretl statistical program

This study models fuel import dependence (FIM), measured as fuel imports as a percentage of merchandise imports, as the dependent variable, Explanatory variables are renewable energy consumption (REC), defined as the share of total final energy consumption; GDP growth (GDP), expressed in annual percentage; crude oil prices (COP), in US dollars per barrel; and trade openness (TOP), measured as total trade as a percentage of GDP. I estimate the relationship using ordinary least squares with FIM as the outcome and REC, GDP, COP, and TOP as regressors, implemented in Gretl statistical software.

4.1 Descriptive Statistics

This section reports summary statistics for 2001 to 2021 for fuel import dependence FIM, renewable energy consumption REC, GDP growth GDP, crude oil prices COP, and trade openness TOP. The figures describe location, dispersion, and shape to gauge scale, volatility, and asymmetry before modeling the relationships among these variables:

Table 2 Summary Statistics, using the observations 2001 - 2021

Variable	Mean	Median	Minimum	Maximum
FIM	7.8240	7.8738	3.5453	13.623
REC	11.610	12.200	6.3000	17.200
GDP	2.5010	2.8303	-5.3049	6.6232
COP	63.205	58.340	19.350	110.80
TOP	129.67	129.88	90.879	156.42

Variable	Std. Dev.	C.V.	Skewness	Ex. kurtosis
FIM	2.3843	0.30474	0.35400	-0.093983
REC	3.7167	0.32014	-0.041956	-1.5031
GDP	3.1346	1.2533	-1.1844	1.0363
COP	27.655	0.43755	0.36197	-0.91908
TOP	19.083	0.14717	-0.60524	-0.56350
Variable	5% Perc.	95% Perc.	IQ range	Missing obs.
FIM	3.6684	13.298	3.6273	0
REC	6.3400	17.180	7.1000	0
GDP	-5.2542	6.5984	3.2046	0
COP	20.427	110.72	47.075	0
TOP	91.256	156.18	28.309	0

Source: Prepared by the researcher based on Gretl statistical program.

Fuel import dependence averages 7.824 percent with a median of 7.874 and a range from 3.545 to 13.623. Relative dispersion is moderate with a coefficient of variation of 0.305 and a mild right skew of 0.354, while excess kurtosis is near zero which is close to a normal shape. Renewable energy consumption averages 11.610 percent and spans 6.300 to 17.200, with a coefficient of variation of 0.320 and an interquartile range of 7.100, indicating meaningful within sample variation. Its skewness is slightly negative at minus 0.042 and excess kurtosis is minus 1.503 which is a flat distribution. GDP growth averages 2.501 percent and is volatile with a coefficient of variation of 1.253, a minimum of minus 5.305 and a maximum of 6.623. The distribution is left skewed at minus 1.184 with excess kurtosis of 1.036 which signals heavy tails consistent with recession episodes. Oil prices average 63.205 dollars per barrel with wide swings between 19.350 and 110.800, a coefficient of variation of 0.438, a mild right skew of 0.362, and a flat shape with excess kurtosis of minus 0.919, The interquartile range is large at 47.075 which reflects strong price cycles that can pass through to the value of fuel imports. Trade openness averages 129.67 percent with relatively low dispersion a coefficient of variation of 0.147 and values between 90.879 and 156.42. The distribution shows a mild left skew at minus 0.605 and excess kurtosis of minus 0.564, and the 5th to 95th percentile band runs from 91.256 to 156.18 which indicates persistently high external integration. Taken together, the moments describe an open economy exposed to oil price cycles, a volatile growth environment, and a renewable share that varies enough to test whether higher REC coincides with lower FIM over time. And figure.1 show us trends for variables:

Figure 1 Trends in the development of study variables

Source: Prepared by the researcher based on Gretl statistical program

Within the period of 20012021, the panels follow a logical story of energy reliance, the energy blend, macro changes, price spikes, and foreign assimilation. Fuel import dependence begins on a high point in 2001, declines through the mid-2000s, before increasing in 20082012, and then begins declining in 2020 followed by a further decrease in 2021. The peak in the middle of the sampling period is in line with the boom in oil prices and high demand of imports whereas the decline in 2013 and further is in line with the consistent increase in renewable energy and, subsequently, lower oil prices. The consumption of renewable energy is projected to increase significantly at an average rate of between 6- 7 percent to approximately 17 percent by the year 2021, and this is an annual growth trend in agreement with the policy support and reduction in costs which gradually replace imported fossil fuels and squeeze the fuel import share. The growth in the GDP is cyclical, and strong contractions in 2009, the imbalanced expansions throughout the 2010s, a pandemic shock in 2020, and a recovery in 2021 are associated with swings in imports demand, which amplifies or suppresses fuel imports movements. Crude oil prices display a classic super-cycle, peaking above 100 dollars per barrel in 2011–2012, collapsing in 2014–2016, dipping again in 2020, and recovering in 2021; these price swings influence the value share of fuel imports even when volumes adjust with a lag. Trade openness climbs from about 90 percent to above 150 in the early 2010s, then moderates, which increases exposure to global price cycles and demand shocks during its ascent and slightly tempers that exposure later. The joint timing matters. The co-movement of fuel import dependence with oil price peaks around 2008–2012 and with the 2020 collapse points to a strong valuation channel, while the persistent rise in renewables aligns with the structural decline in fuel import dependence after 2013. The data therefore motivate an empirical specification in which renewable energy exerts a negative effect on fuel import dependence, oil prices raise it through price pass-through, GDP growth shifts it via the demand channel, and trade openness governs the economy's sensitivity to external shocks.

4.2 Measuring linear correlations

We measure Pearson linear correlations for all variable pairs over 2001–2021. Significance is assessed with a two-tailed 5 percent test using a critical absolute value of 0.4329 for n equal to 21.

The null hypothesis for each pair states that the population correlation equals zero.

The alternative hypothesis states that the population correlation differs from zero.

Table 3 Correlation coefficients, using the observations 2001 - 2021
5% critical value (two-tailed) = 0.4329 for n = 21

	TOP	COP	GDP	REC	FIM
FIM	-0.4138	0.1308	-0.0937	-0.5492	1.0000
REC	0.7899	0.3223	-0.2846	1.0000	
GDP	0.0636	-0.2067	1.0000		
COP	0.4626	1.0000			
TOP	1.0000				

Source: Prepared by the researcher based on Gretl statistical program

The correlation between fuel import dependence and renewable energy consumption equals minus 0.5492 and is statistically significant, indicating that a higher renewable share associates with a lower fuel import share through a substitution channel and improved energy self-reliance. Renewable energy consumption correlates strongly and positively with trade openness at 0.7899 and is significant, consistent with openness enabling technology diffusion, capital inflows, and equipment imports that scale renewables. Crude oil prices and trade openness show a positive and significant association at 0.4626, suggesting that oil price upswings inflate the value of trade and that global demand cycles raise both prices and cross-border flows. Other pairs are not significant at the 5 percent level. Fuel import dependence with GDP growth at minus 0.0937 and with oil prices at 0.1308 shows weak links, consistent with offsetting price and volume effects in a share metric and with parallel movements of fuel and non-fuel imports during growth swings. The correlation between fuel import dependence and trade openness at minus 0.4138 falls just short of the threshold, hinting that greater integration may coincide with diversification of the import basket and efficiency gains but without clear statistical confirmation, Renewable energy consumption shows weak correlations with GDP growth at minus 0.2846 and with oil prices at 0.3223, which points to policy and structural drivers rather than short-run macro or price movements. GDP growth exhibits small and insignificant correlations with oil prices at minus 0.2067 and with trade openness at 0.0636, indicating that external price shocks and openness do not map one for one into near-term growth within this sample.

4.3 Verify modeling assumptions

This study validates the assumption of normal distribution of annual series variables before estimation using four common tests: Doornik–Hansen, Shapiro–Wilk, Lilliefors, and Jarque–Bera, as presented in Table 4.

The null hypothesis H0 states that each variable follows a normal distribution.

The alternative hypothesis H1 states that the variable does not follow a normal distribution.

Table 4 Test for normality

Variable	Doornik–Hansen (p-value)	Shapiro–Wilk (p-value)	Lilliefors (p-value)	Jarque–Bera (p-value)
FIM	1.101 (0.5767)	0.9685 (0.7001)	0.1218 (≈0.56)	0.4463 (0.8000)
REC	5.0400 (0.0805)	0.9036 (0.0411)	0.1626 (≈0.15)	1.9831 (0.3710)
GDP	6.4083 (0.0406)	0.8802 (0.0148)	0.1859 (≈0.05)	5.8497 (0.0537)
COP	1.6594 (0.4362)	0.9437 (0.2572)	0.1324 (≈0.43)	1.1977 (0.5494)

TOP	2.6898 (0.2606)	0.9356 (0.1783)	0.1246 (≈0.53)	1.5599 (0.4584)

Source: Prepared by the researcher based on Gretl statistical program

Table 4 indicates clear normality for FIM, COP, and TOP since all reported p values exceed 0.05 across tests. REC shows mixed evidence. Shapiro–Wilk rejects normality with p equal to 0.0411, while Doornik–Hansen, Lilliefors, and Jarque–Bera do not reject. This suggests a mild departure from normality that is not uniform across test statistics. GDP shows the strongest departure. Doornik–Hansen equals 0.0406 and Shapiro–Wilk equals 0.0148, which reject normality, while Lilliefors sits at about 0.05 and Jarque–Bera at 0.0537 on the borderline. In small samples, such patterns often reflect skewness and heavy tails around recession and recovery years. The modeling implication is straightforward.

According to the above, we find that the use of least squares regression achieves the assumption through the normal or close-to-normal distribution of data, and thus the regression model can be used using the least squares method.

This section examines the presence of multicollinearity among the explanatory variables using the Belsley–Kuh–Welsch diagnostic based on eigenvalues, condition indexes, and variance ratio analysis as shown in Table 5.

The null hypothesis H0 is that there is no harmful multicollinearity in matrix X, i.e., no small dimension with an eigenvalue close to zero, accompanied by a condition index ≥30, and where variance ratios ≥0.5 for two or more variables cluster.

The alternative hypothesis H1 is that harmful multicollinearity exists, such that one or more dimensions with a high condition index cluster and where variance ratios ≥0.5 for several variables cluster.

Table 5 Belsley–Kuh–Welsch collinearity diagnostics

λ (Eigenvalue)	Condition Index	REC	GDP	COP	TOP
3.302	1.000	0.003	0.019	0.009	0.002
0.595	2.356	0.004	0.560	0.016	0.000
0.092	6.007	0.105	0.013	0.757	0.013
0.012	16.717	0.889	0.409	0.218	0.985
Smallest eigenvalue = 0.0118 Condition index ≥ 30 → none (0) Condition index between 10 and 30 → one case (16.717) Variance proportions ≥ 0.5 at problematic condition index: REC (0.889) and TOP (0.985					

Source: Prepared by the researcher based on Gretl statistical program

Table 5 indicates no severe multicollinearity. No condition index reaches 30. One index equals 16.717. At that index, variance proportions are high for REC 0.889 and TOP 0.985, while GDP 0.409 and COP 0.218 stay below 0.5. This pattern signals one moderate collinearity dimension mainly linking REC and TOP. The smallest eigenvalue equals 0.0118, which is small but consistent with the observed condition index. Earlier dimensions show a condition index of 6.007 with a large variance share for COP 0.757 alone, which is not problematic because the BKW flag requires multiple variables loading heavily on the same high index. Taken together, the diagnostics support H0 in the strict BKW sense.

Therefore, according to the above, all variables can be included in the model with no statistical significance due to the problem of multicollinearity.

4.4 Modeling and Hypothesis Testing

The Modeling and Hypothesis Testing section relies on estimating an ordinary linear regression model (OLS) for annual data covering 2001–2021 with 21 observations. The dependency on fuel imports (FIM) was modeled as a dependent variable on renewable energy consumption (REC), real GDP growth, Brent crude oil price (COP), and trade openness (TOP), Model validity tests were performed to ensure the normality of residuals, the absence of autocorrelation, heteroscedasticity, the integrity of the functional formula, and the stability of coefficients. Table 6 presents the basic results of this model. We test four directional hypotheses:

H1 Renewable energy consumption reduces fuel import dependence, $\beta\_REC < 0$, ceteris paribus.

H2 Real GDP growth increases fuel import dependence in the short run, $\beta\_GDP > 0$.

H3 Higher Brent crude oil prices increase fuel import dependence through valuation effects, $\beta\_COP > 0$.

H4 Greater trade openness increases fuel import dependence by transmitting external shocks, $\beta\_TOP > 0$.

We also test the joint significance of the regressors and verify OLS assumptions using standard diagnostics before inference:

Table 6 Model OLS, using observations 2001-2021 (T = 21)
Dependent variable: FIM

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	11.0818	3.64104	3.044	0.0077	***
REC	−0.511285	0.239419	−2.136	0.0485	**
GDP	−0.203777	0.180425	−1.129	0.2754	
COP	0.0246305	0.0193319	1.274	0.2208	
TOP	0.0125776	0.0492288	0.2555	0.8016	

Mean dependent var	7.823980	S.D. dependent var	2.384257
Sum squared resid	61.56193	S.E. of regression	1.961535
R-squared	0.458528	Adjusted R-squared	0.323160
F(4, 16)	3.387271	P-value(F)	0.034495
Log-likelihood	−41.09068	Akaike criterion	92.18136
Schwarz criterion	97.40398	Hannan-Quinn	93.31480
rho	−0.002870	Durbin-Watson	1.999924

Source: Prepared by the researcher based on Gretl statistical program

The OLS model for 2001–2021 explains a meaningful share of variation in FIM. The joint F-test equals 3.387 with df 4 and 16 and $p = 0.0345$, so the regressors are jointly significant at 5 percent. R^2 is 0.459 and adjusted R^2 is 0.323, which indicates moderate explanatory power after penalizing for four regressors and 21 observations. The standard error of regression is

1.962 versus a standard deviation of the dependent variable of 2.384, so the model reduces unexplained dispersion yet leaves sizable variation for factors outside the specification. The Durbin-Watson statistic equals 1.9999 and the corresponding residual autocorrelation estimate rho = −0.0029, both consistent with no first-order serial correlation. The log-likelihood is −41.091, and the AIC 92.181, Schwarz 97.404, and Hannan-Quinn 93.315 provide baselines for comparing alternative specifications with the same sample.

At the coefficient level, the constant is 11.0818 with SE 3.6410, t = 3.044, p = 0.0077. It is precisely estimated and statistically different from zero at 1 percent, implying that when REC, GDP, COP, and TOP are at their reference levels the baseline of FIM is high. A 95 percent confidence interval is roughly [3.363, 18.801]. REC is −0.5113 with SE 0.2394, t = −2.136, p = 0.0485. The sign is negative and statistically significant at 5 percent. The 95 percent interval is about [−1.019, −0.004], which barely excludes zero and explains the borderline p-value. Interpreted as a partial effect, a one-unit rise in REC lowers FIM by about 0.51 units, holding other regressors fixed. GDP is −0.2038 with SE 0.1804, t = −1.129, p = 0.275. The point estimate is negative but imprecise; the 95 percent interval [−0.586, 0.179] includes economically small positive and negative effects, so the data do not support a directional claim. COP is 0.02463 with SE 0.01933, t = 1.274, p = 0.221. The effect is positive in sign but not significant; the 95 percent interval [−0.016, 0.066] spans zero and only modest magnitudes. TOP is 0.01258 with SE 0.04923, t = 0.256, p = 0.802. The estimate is near zero with a wide 95 percent interval [−0.092, 0.117]; the data are uninformative about a TOP effect once other variables are controlled for.

The residual sum of squares is 61.562. With 16 residual degrees of freedom, the implied error variance is about 3.848, and its square root matches the reported regression SE of 1.962, which confirms internal consistency of the output.

Statistical testing against the stated hypotheses yields a clear pattern.

- H1 posited a negative effect of REC on FIM. The estimate is negative and significant at the 5 percent level with $p = 0.0485$, so H1 is supported.
- H2 posited a positive short-run effect of GDP on FIM. The estimate is negative with $p = 0.275$, so the data do not support H2 and you fail to reject a zero effect.
- H3 posited that higher COP raises FIM. The sign is positive as hypothesized, but $p = 0.221$, so you fail to reject the null of no effect.
- H4 posited that greater TOP raises FIM. The estimate is positive but very imprecise with $p = 0.802$, so you also fail to reject the null. The model's overall F-test indicates at least one regressor matters in combination, and the coefficient results show that REC is the driver of significance in this specification.

The negative REC coefficient implies that higher renewable energy consumption is associated with lower fuel import dependence after conditioning on income growth, oil prices, and trade openness. The magnitude is meaningful relative to the scale of FIM in the sample mean of 7.824. The GDP coefficient is negative on average rather than positive, which may reflect structural shifts where growth coincides with efficiency gains, substitution away from imported fuels, or expansion of domestic energy supply. The COP estimate is small and imprecise, suggesting that international oil price movements have limited direct leverage on FIM once REC and macro conditions are accounted for, possibly because of pricing regimes, hedging, or supply contracts that damp short-run pass-through, The TOP estimate centers near zero, which points to a weak contemporaneous link between aggregate trade openness and fuel import dependence once other drivers are included. Together, the fit metrics and Durbin-Watson near two indicate a statistically coherent linear specification without detectable first-order autocorrelation.

To verify the validity of the model, we conduct diagnostic tests on the model residuals and find:

The first objective is to examine the normality of the OLS model's residuals over the period 2001–2021 using a chi-square test on the residuals frequency distribution with seven degrees of freedom, an estimated mean close to zero, and a standard deviation of 1.96154 to control the scale.

The null hypothesis H0 states that the model's residuals follow a normal distribution with a mean equal to zero and a constant variance,

The alternative hypothesis H1 states that the residuals do not follow a normal distribution:

Table 7 Test normal distribution for residual

Frequency distribution for residual, obs 1-21
number of bins = 7, mean = -2.98174e-015, sd = 1.96154
Test for null hypothesis of normal distribution:
Chi-square(2) = 3.200 with p-value 0.20187

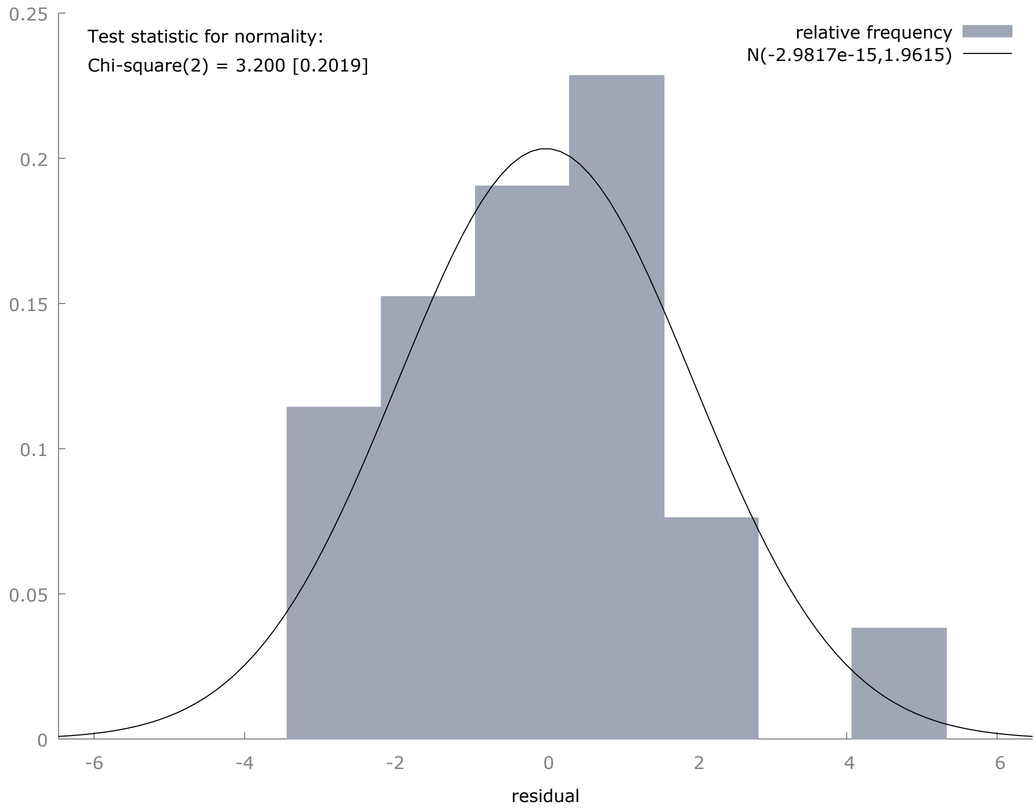
Source: Prepared by the researcher based on Gretl statistical program

The chi-square goodness-of-fit test reports χ^2 with 2 degrees of freedom equal to 3.200 and a p-value of 0.20187. You fail to reject H0 at the 10 percent level and at the 5 percent level. The sample has 21 observations and the histogram uses seven bins, which limits power yet still shows residuals centered at essentially zero with a reported mean of -2.98×10^{-15}.

The reported standard deviation of 1.96154 aligns with the model's standard error of regression, which indicates coherent scaling of residuals. The test outcome provides no statistical evidence against normality, so conventional small-sample t and F inference for the OLS coefficients is likely reliable under this assumption.

The following figure.2 shows that the distribution of residuals is strongly consistent with the normal distribution:

Figure 2 normal distribution for residual



Source: Prepared by the researcher based on Gretl statistical program

The Ramsey RESET test in Table 8 aims to verify the adequacy of the OLS model formulation in terms of functional form and the possibility of missing variables by adding the squares and cubes of the appropriate values or powers of the explanatory variables to an expanded equation and then examining their explanatory power, The null hypothesis states that the model formulation is adequate and the additional terms have no explanatory power,

The alternative hypothesis states that the model is not properly specified and there is an inadequacy in the functional form or missing variables that can be explained by the squared or cubic terms:

Table 8 RESET test for specification

RESET Test Type	Null Hypothesis	Test Statistic (F)	p-value
Squares and Cubes	Specification is adequate	1.5314	0.250
Squares only	Specification is adequate	0.2316	0.637
Cubes only	Specification is adequate	0.3400	0.568

Source: Prepared by the researcher based on Gretl statistical program

The RESET results indicate no specification error. The squares and cubes version reports F equal to 1.5314 with p equal to 0.250. The squares only version reports F equal to 0.2316 with p equal to 0.637. The cubes only version reports F equal to 0.3400 with p equal to 0.568. Each p value exceeds conventional levels. You fail to reject the null of adequate specification under all variants. The evidence does not support omitted nonlinear terms of second or third order in this sample. This supports the linear functional form used in Table 6 for the period 2001 to 2021.

The table.9 motivates White's test to assess variance constancy in the OLS residuals for 2001 to 2021.

The null hypothesis states that errors are homoskedastic given the regressors and their functions.

The alternative states that errors are heteroskedastic and the variance depends on one or more functions of the regressors:

Table 9 White's test for heteroskedasticity

White's test for heteroskedasticity
OLS, using observations 2001-2021 (T = 21)
Dependent variable: uhat^2
Test statistic: TR^2 = 16.525364,

with p-value = P(Chi-square(14) > 16.525364) = 0.282354

Source: Prepared by the researcher based on Gretl statistical program

The test reports TR^2 equal to 16.525 with 14 degrees of freedom and p equal to 0.282354. You fail to reject homoskedasticity at the 10 percent level and at the 5 percent level. Conventional OLS standard errors and the associated t and F statistics remain defensible under this assumption. The auxiliary regression behind White's test is flexible, the evidence does not indicate variance misspecification.

The Breusch -Godfrey test for first-order autocorrelation aims to verify the independence of the residuals of the OLS model during 2001–2021 at the first lag based on an auxiliary regression of the model's residuals.

- The null hypothesis H0 states that there is no first-order autocorrelation in the residuals.
- The alternative hypothesis H1 states that there is first-order autocorrelation:

Table 10 Breusch-Godfrey test for first-order autocorrelation

Breusch-Godfrey test for first-order autocorrelation
OLS, using observations 2001-2021 (T = 21)
Dependent variable: uhat
Test statistic: LMF = 0.000150,
with p-value = P(F(1,15) > 0.000149855) = 0.99
Alternative statistic: TR^2 = 0.000210,
with p-value = P(Chi-square(1) > 0.000209794) = 0.988
Ljung-Box Q' = 0.000196627,
with p-value = P(Chi-square(1) > 0.000196627) = 0.989

Source: Prepared by the researcher based on Gretl statistical program

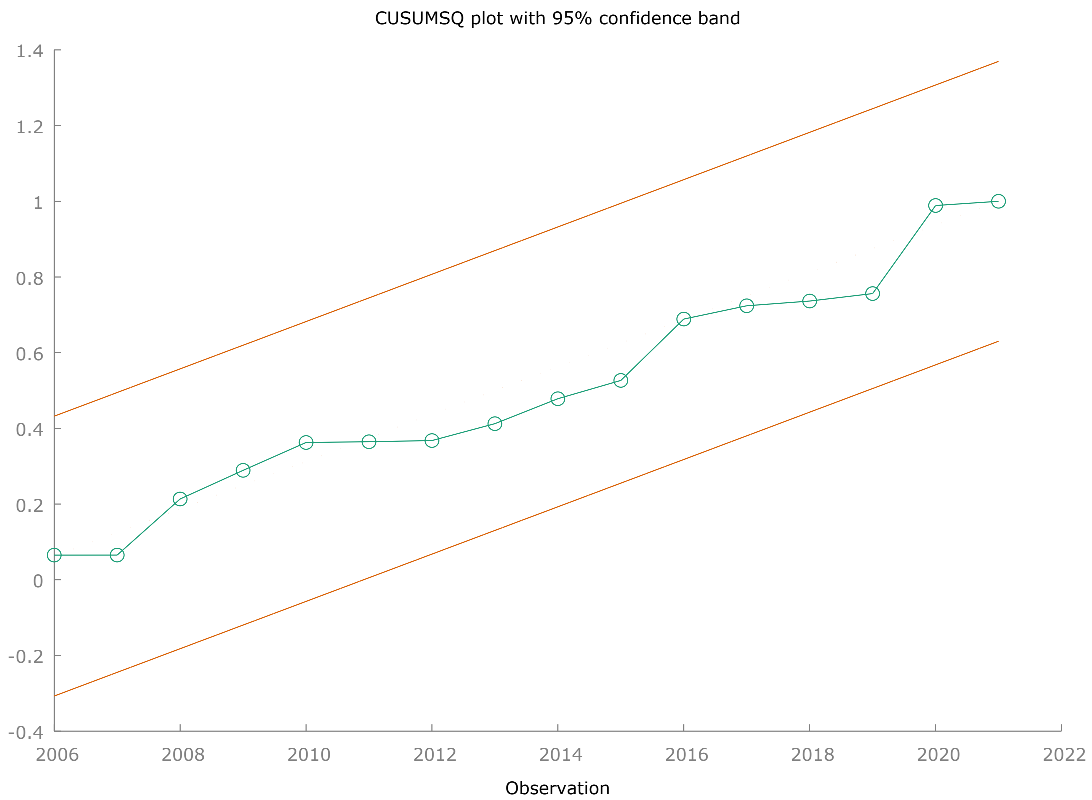
The Breusch–Godfrey outputs point to no autocorrelation. The LMF equals 0.000150 with p = 0.99 under F(1, 15). The alternative LM form reports TR^2 = 0.000210 with p = 0.988. The Ljung–Box Q′ equals 0.0001966 with p = 0.989. Each statistic is near zero and each p-value is far above 0.10. You fail to reject H0. Residuals behave like white noise at lag 1. This supports the earlier Durbin–Watson near two and aligns with a well-specified static model. OLS coefficient estimates and their t and F tests do not require autocorrelation corrections in this setting.

By drawing the figure.3, we aim to test the stability of the OLS model coefficients over the period 2006–2021 using the CUSUM of Squares test based on inverse residuals.

The null hypothesis H0 states that the coefficients are stable, there is no structural break, and variance is homogeneous across time.

The alternative hypothesis H1 states that there is instability or a structural break that causes the cumulative path to deviate from the 5 % significance threshold.

Figure 3 CUSUMSQ Test for Results



Source: Prepared by the researcher based on Gretl statistical program

The plotted cumulative sum of squared recursive residuals stays inside the 5 percent bands for all dates. The path rises monotonically and approaches one near the end of the sample yet never crosses the critical lines. we fail to reject the null of parameter constancy. The model shows no structural break over 2006–2021. Coefficient estimates remain valid for the whole sample. The late rise around 2019–2021 does not breach the band.

5-Discussion of Results and Recommendations

The estimated OLS model uses annual data for Czechia from 2001 to 2021 with FIM as the dependent variable and REC, GDP growth, Brent COP, and TOP as regressors. Joint significance holds $F_{4,16}$ equals 3.387 with p equals 0.0345 and R^2 equals 0.459 with adjusted R^2 equals 0.323. Diagnostics support validity. Durbin–Watson is 1.9999. White's test p equals 0.282. Breusch–Godfrey p equals 0.989. RESET p equals 0.250. Residual normality holds with χ^2 p equals 0.202. Belsley–Kuh–Welsch shows a moderate REC–TOP dimension but no harmful multicollinearity. Only REC is statistically significant. β_{REC} equals −0.5113 with p equals 0.0485. GDP, COP, and TOP are imprecise with p values 0.275, 0.221, and 0.802. A one percentage point rise in REC lowers FIM by about 0.51 percentage points. Sample size equals 21, so inference remains conservative but coherent.

The economic story is consistent and actionable. Mean FIM equals 7.824. Raising REC by 2 points lowers FIM by about 1.02 points which is roughly 13 percent of the mean fuel import share. The weak GDP effect likely reflects efficiency gains, sectoral change, and domestic substitution that offset demand pressure. The small COP coefficient suggests policy, taxation, contract structures, and synchronized movements in non fuel imports dilute pass through in this share metric. The near zero TOP effect indicates that openness delivers offsetting forces diversification and clean technology inflows on one side and exposure on the other. Use the elasticities to stress test policy. With the point estimates, a 10 dollar oil shock implies about 0.25 points higher FIM while a 0.5 point REC increase offsets that rise at the margin. Prioritize REC additions that displace oil and gas in heating and transport. Accelerate heat pumps, district heating upgrades, and EV uptake. Maintain grid flexibility through storage and interconnection to lock in the substitution gains.

The findings align with European evidence that renewables reduce reliance on imported fuels and stabilize prices, The negative REC effect is consistent with fossil substitution across power, heat, and mobility and with lower price exposure documented for Europe and case studies, while the muted GDP and COP effects echo work on incomplete pass through and evolving intensity during the transition (Hong, 2022; Deltas, 2024; Pavlík, 2025). The broader security framing and EU monitoring support the policy relevance of reducing the fuel import share through a credible renewable mix and flexibility investments (LaBelle, 2024; Eurostat, 2024; Sterling, 2025), Trade focused studies explain the mixed role of openness and justify interaction work in robustness, while diversification results warn to track shifting dependencies toward minerals and equipment as REC rises (Ilechukwu and Lahiri, 2022; Eschmann and Jochem, 2025; Lekavičius et al., 2024; Fikru and Kilinc-Ata, 2024).

The study recommends, Keep expanding REC with priority on heating and transport where import displacement is largest. Pair capacity with storage, demand response, and cross border links to translate REC into lower import needs. Preserve openness for clean tech but monitor mineral and equipment exposures with supplier diversification. Run robustness already planned in the study interactions of REC with oil prices and openness, IV using lagged REC, and sample splits around 2013 to verify stability and to refine the policy elasticities for budgeting and procurement.

6-Conclusion

This study shows that expanding renewable energy penetration materially reduces the fuel import share in Czechia over 2001–2021. The estimated OLS model with Fuel imports (% of merchandise imports) as the dependent variable and Renewable energy consumption (% of total final energy consumption), GDP growth, Brent crude price, and trade openness as regressors passes standard specification and diagnostics and delivers a coherent fit. The core quantitative finding is a precise and negative Renewable energy consumption (% of total final energy consumption) effect, with a one-percentage-point increase in Renewable energy consumption (% of total final energy consumption) associated with about a 0.51-point decline in Fuel imports (% of merchandise imports), while the estimated effects of growth, oil prices, and openness are statistically weak within this sample. The economic meaning is direct. Renewables substitute for imported fossil fuels across power, heat, and mobility, and the resulting reduction in the import share is large enough to be policy relevant. The muted roles of macro growth and oil prices indicate that efficiency gains, sectoral change, taxation, and contracting reduce pass-through into the import share metric, and the near-zero trade-openness effect suggests offsetting channels between diversification benefits and exposure. The policy message is clear. Prioritize incremental Renewable energy consumption (% of total final energy consumption) additions in heating and transport, pair capacity with storage, interconnection, and demand response to convert nameplate capacity into dependable import displacement, and preserve openness to clean-technology inflows while diversifying upstream supply chains for critical equipment and materials. The paper contributes an actionable elasticity for an EU member during the transition, supported by a transparent specification and comprehensive diagnostics. It also identifies the boundaries of inference that invite further work. Future research should test robustness with interaction terms for REC and oil prices, alternative openness measures, and instrumental-variables designs, extend to panel and sectoral settings, explore dynamic models beyond static OLS, and complement the share metric with physical dependency and scenario-based stress tests, Taken together, the evidence supports a pragmatic path for energy security, Steady expansion of renewables, backed by system flexibility, delivers measurable reductions in fuel import dependence and improves macroeconomic resilience.

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