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Effects of oil price volatility on the economy and energy in morocco (1980-2020): causal modeling and machine learning

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Résumé
Cet article analyse l'effet des fluctuations des prix du pétrole sur l'économie et l'énergie au Maroc entre 1980 et 2020, dans un contexte marqué par une forte dépendance énergétique extérieure. L'objectif principal est d'estimer l'effet causal des chocs pétroliers sur le PIB par habitant, en intégrant dans l'analyse des politiques publiques telles que les subventions énergétiques et les investissements dans les énergies renouvelables. Pour ce faire, une approche économétrique robuste basée sur la méthode du Double Machine Learning (DML) est utilisée, permettant de contrôler l'endogénéité des variables et les biais liés aux facteurs de confusion (inflation, gouvernance énergétique, coûts d'accès à l'énergie, etc.). Le modèle repose sur une fonction de production de type Cobb-Douglas intégrant explicitement la consommation d'énergie comme facteur clé. Les données utilisées proviennent de sources fiables telles que la Banque mondiale, l'Agence internationale de l'énergie et le Haut-Commissariat au Plan, et couvrent la période 1980-2020. Toutes les variables quantitatives ont été transformées logarithmiquement pour garantir la stabilité statistique et une interprétation élastique. Les résultats montrent que les prix du pétrole exercent un effet modéré mais significatif sur le PIB, avec un effet interquartile estimé à +4,46 %. En revanche, la réforme des subventions énergétiques présente un effet causal plus fort, estimé à +5,72 %. Ces résultats soulignent l'importance de politiques structurelles appropriées pour renforcer la résilience macroéconomique face à la volatilité énergétique.

Mots-clés : *Prix du pétrole, Maroc, PIB par habitant, Subventions énergétiques, Double apprentissage automatique, Transition énergétique.*

Abstract
This article analyzes the effect of oil price fluctuations on the economy and energy in Morocco between 1980 and 2020, in a context marked by strong external energy dependence. The main objective is to estimate the causal effect of oil shocks on GDP per capita, integrating public policies such as energy subsidies and investments in renewable energies into the analysis. To do this, a robust econometric approach based on the Double Machine Learning (DML) method is used, allowing for the control of the endogeneity of variables and biases related to confounding factors (inflation, energy governance, energy access costs, etc.). The model is based on a Cobb-Douglas type production function explicitly integrating energy consumption as a key factor. The data used come from reliable sources such as the World Bank, the International Energy Agency, the High Commission for Planning, and cover the period 1980–2020. All quantitative variables were log-transformed for statistical stability and elastic interpretation. The results show that oil prices exert a moderate but significant effect on GDP, with an estimated interquartile effect of +4.46%. In contrast, energy subsidy reform exhibits a stronger causal effect, estimated at +5.72%. These results highlight the importance of appropriate structural policies to strengthen macroeconomic resilience in the face of energy volatility.

Keywords: *Oil prices, Morocco, GDP per capita, Energy subsidies, Double machine learning, Energy transition.*

INTRODUCTION

Oil price fluctuations play a central role in the global economy. As a strategic commodity, oil directly influences economic cycles, inflation levels, energy security, and geopolitical stability. Historically, sharp increases or decreases in oil prices have coincided with major economic crises, such as that of 2008 or, more recently, the post-COVID-19 period, highlighting the sensitivity of the global economy to this highly volatile market (Wang et al., 2022).

The impact of oil price shocks varies depending on the level of development and the nature of the economies concerned. For advanced countries, the tertiarization of the economy has reduced energy intensity per unit of GDP, partially mitigating the effect of price increases. However, for emerging or industrializing countries, which are more dependent on energy-intensive sectors, the impacts remain significant (Looney, 2002). More recently, several studies show that oil price volatility linked to the war in Ukraine, the global energy transition, and geopolitical uncertainties has intensified macroeconomic imbalances, affecting fiscal balances, exchange rates, productive investment, and growth, particularly in net energy-importing economies (Riaz et al., 2020), (Macovei, 2023).

At the same time, the effects of oil prices on financial markets and clean energy investments are becoming increasingly significant. Oil price increases can temporarily boost ESG indices or encourage the use of renewable energy, although this remains highly dependent on the national context (Jiang et al., 2024).

In this international context, Morocco is particularly exposed to fluctuations in oil prices due to its high external energy dependence. As a net importer without significant hydrocarbon production, the Kingdom remains vulnerable to price increases on global markets. These translate into higher energy bills, pressure on the trade deficit, and an inflationary effect on commodities. This structural energy dependence has been highlighted on several occasions, particularly during recent shocks related to the war in Ukraine (Moustabchir et al., 2024).

Unlike advanced economies that have reduced their energy intensity, the Moroccan economy remains dominated by energy-intensive sectors, such as transportation, irrigated agriculture, and certain industrial sectors. These sectors bear the brunt of rising energy costs, which slows real GDP growth during periods of high oil prices (Azzi & Masih, 2018).

Furthermore, the indirect effects of oil price shocks on public finances and monetary stability are exacerbated by the historical fuel subsidy policy, which has long amplified the budgetary impact of these price increases (Vidican Auktor & Loewe, 2022). Although Morocco has undertaken subsidy reforms since 2015, the transition to an economy more resilient to oil price shocks remains incomplete.

Finally, rising climate concerns and the national sustainable development strategy have paved the way for a gradual energy transition based on renewable energies, but this only partially mitigates the short-term effects of oil price fluctuations (Belcaid, 2024), (Nchofoung, 2024a).

Therefore, this article aims to estimate the causal effect of oil price fluctuations on GDP per capita in Morocco, a country heavily dependent on energy imports. In an international context marked by oil volatility and geopolitical uncertainties, this study is part of the theories of supply and demand shocks (Blanchard, 1989), economic resilience, and energy transition. To do this, a methodology based on Double Machine Learning is used to control for confounding variables such as inflation or subsidies, ensuring a robust estimation of the causal effect (Chernozhukov et al., 2018). Subsequently, counterfactual decision trees are used to simulate the impact of alternative policies such as the removal of subsidies or the introduction of a carbon tax (Hatamyar & Kreif, 2023). This approach not only quantifies the macroeconomic effects of oil shocks, but also assesses the adaptive capacity of the Moroccan economy. The data used come from the World Bank, the International Energy Agency and national sources for the period 1980-2020.

To do this, this article will be divided into four sections: the first will present the literature review; the second will present the methodological framework; the third will describe the data used; and the last will analyze the results obtained.

I. LITERATURE REVIEW

Oil price shocks are defined as sudden and unforeseen fluctuations in oil prices. In reality, these shocks can result from geopolitical factors (conflicts, sanctions), natural disasters, or imbalances between supply and demand (Venditti & Veronese, 2020).

In this context, oil price shocks continue to have profound effects on the economies of developing countries, particularly those whose structure depends largely on hydrocarbon exports or imports. As the energy transition becomes a central issue in the fight against climate change and for energy security, these fluctuations make this transformation more complex and often costlier to implement (Dąbrowski et al., 2022).

In Africa, for example, oil price shocks have been identified as a major obstacle to the energy transition. In this context, Nchofoung, (2024b) conducted a study of 53 African countries between 2000 and 2020, demonstrating that sudden increases in oil prices hinder the adoption of renewable energy, particularly in exporting countries. This dynamic is not found in importing countries, highlighting the importance of national energy status in responding to exogenous shocks. Furthermore, this study highlights the inability of oil shocks to explain persistent inequalities between urban and rural areas in terms of access to clean energy.

This heterogeneity of effects depending on the energy profile of countries is confirmed by other studies comparing oil-exporting and oil-importing economies. Oil shocks increase economic volatility, but their effects on production differ significantly: some exporting countries, such as Russia or Iran, experience an increase in their economic activity, while importing countries such as the Philippines or Turkey experience contractions, often due to defensive adjustment policies, such as lower interest rates to offset rising energy import costs (Değirmen et al., 2023).

In this context, international trade appears to be a potential buffer against the effects of shocks. By integrating trade flows between exporting and importing countries, another study reveals that these trades can partially mitigate the impact of oil price fluctuations on economic growth. However, this resilience is more pronounced among developing exporters, who benefit directly from rising prices, even if this windfall remains vulnerable to declining global demand (Moshiri & Kheirandish, 2024).

Iran provides an instructive example of a highly oil-dependent economy, where oil price shocks generate ambivalent effects. While export revenues boost GDP and consumption in the short term, the non-oil sector contracts, employment declines, and macroeconomic imbalances widen, highlighting the limitations of a hydrocarbon-based model (Faraji & Zahra, 2014).

Paradoxically, Esmaeili et al., (2024) suggest that oil price shocks can serve as a trigger for the energy transition. Indeed, historical episodes such as the Iranian Revolution and the 2008 financial crisis have triggered extreme increases in oil prices, making renewable alternatives more attractive in the long term. These situations encourage governments to strengthen incentive policies and investments in clean energy, although the effects are often delayed.

Nevertheless, despite these opportunities, developing countries' persistent dependence on oil revenues hinders the implementation of ambitious structural reforms. Governments are reluctant to abandon a strategic source of revenue, especially in times of economic instability. Thus, while oil shocks can sometimes stimulate interest in the transition, institutional inertia and budgetary constraints often limit real progress (Ryan & Michieka, 2024).

From this perspective, international frameworks such as the Paris Agreement play a structuring role for climate and energy policies. They allow low-income countries to access support mechanisms, thus strengthening their adaptation capacities in the face of oil volatility while integrating them into a comprehensive climate strategy. Strengthening Nationally Determined Contributions (NDCs) and international financial commitments are essential to align local ambitions with global goals (Bakhsh et al., 2024).

Moreover, some developing countries are already showing encouraging trends. Kenya, for example, has invested massively in geothermal and solar energy, reducing its dependence on hydrocarbons while improving access to energy in rural areas. Morocco, for its part, has distinguished itself with the Noor solar power plant, one of the largest in the world, which helps secure energy supplies and attract foreign capital. These examples highlight that, despite initial constraints, strong political will and well-targeted international support can transform vulnerabilities into levers for development (Agoundedemba et al., 2023).

Furthermore, for several years, fluctuations in oil prices have continued to affect the global economy. In countries that rely heavily on energy imports, such as Morocco, these fluctuations are not simply statistics: they translate concretely into strains on public finances, a rising cost of living, and a weakening of macroeconomic balances. Research clearly highlights this particular exposure of net importing economies to oil shocks, particularly through their effects on growth, inflation, and the balance of payments (Ritahi & Echaoui, 2025).

In Morocco's case, this energy dependence is nothing new. Sudden increases in oil prices have often put a strain on the state budget, while affecting household purchasing power and business competitiveness. Available data shows that oil shocks weigh heavily on the country's energy bill, with direct consequences for fiscal and trade balances (Sekkach & Boubrahimi, 2022).

It is in this context that the Kingdom decided, in the early 2010s, to accelerate its energy transition. The ambition is clear: to reduce dependence on fossil fuels and secure long-term energy supplies. Morocco has thus embarked on a vast program to develop renewable energies (solar, wind, and hydroelectric) with a stated objective of increasing their share to more than 52% of the energy mix by 2030 (Daoudi, 2024).

And it seems that, against all odds, rising oil prices can sometimes play a positive role. Some recent studies suggest that these shocks can encourage investment in more sustainable sectors. In Morocco, there has been growing interest in "green" financial assets, particularly those aligned with ESG criteria, in a context where high fossil fuel prices are encouraging the search for more resilient and less volatile alternatives (Berahab, 2024).

But the effects of oil price shocks are not always the same, and everything depends on their origin. When they arise from a supply disruption, for example, a war or a geopolitical crisis, importing economies like Morocco's tend to slow down. On the other hand, when it comes to shocks linked to global demand, the impacts can be more nuanced, influenced by the state of the global economy and market responses.

II. Methodological framework

This section presents the methodological framework used to estimate the causal effect of oil prices on the Economy and Energy in Morocco. It uses the double machine learning approach, which corrects for biases related to confounding variables.

1.1. Theoretical Model: Energy-Dependent Cobb-Douglas Production Function

In this section, we use a Cobb-Douglas production function explicitly incorporating energy as a production factor, in order to capture the structural effects of oil shocks on national output (Oryani et al., 2021).

Step 1: Specification of the Production Function

Real output at time t, denoted Y_t, depends on physical capital K_t, labor L_t, and energy consumption E_t, according to the following expression:

$$Y_t = A_t \cdot K_t^{\alpha} \cdot L_t^{1-\alpha} \cdot E_t^{\beta} \quad (1)$$

Where:

- A_t is total factor productivity (TFP), influenced by energy reforms and technological efficiency,
- $0 < \alpha < 1$ reflects decreasing returns to capital,
- $\beta > 0$ captures the elasticity of output with respect to energy.

Step 2: Log-Linear Transformation

To facilitate econometric estimation, we apply the natural logarithm to equation (1):

$$\ln Y_t = \ln\left(A_t \cdot K_t^{\alpha} \cdot L_t^{1-\alpha} \cdot E_t^{\beta}\right) \quad (2)$$

Using logarithmic properties, we obtain:

$$\ln Y_t = \ln A_t + \alpha \ln K_t + (1-\alpha) \ln L_t + \beta \ln E_t \quad (3)$$

Step 3: Econometric Formulation with Error Term

To account for unobserved shocks (e.g., technology, climate, international context), we introduce a random error term ε_t :

$$\ln Y_t = \ln A_t + \alpha \ln K_t + (1-\alpha) \ln L_t + \beta \ln E_t + \varepsilon_t \quad (4)$$

Statistical assumptions:

- $\varepsilon_t \sim \mathcal{N}(0, \sigma^2)$: normality and homoskedasticity of the error term,
- $E[\varepsilon_t \mid K_t, L_t, E_t] = 0$: strict exogeneity of the input variables.

This theoretical model provides the logical foundation for linking energy input E_t, which is itself dependent on oil prices X_t, to national output. It forms the basis for the causal estimation developed in the following sections.

Step 3: Linking Oil Prices (X_t) and Energy Demand (E_t) - A Mathematical Demonstration

To complete the theoretical foundation of the model, it is essential to establish the relationship between energy consumption and oil prices. Given Morocco's heavy dependence on imported fossil fuels-over 90% of its energy needs any variation in global oil prices directly influences domestic energy consumption and, indirectly, economic output.

1.2. Energy Demand Model

We model the demand for energy E_t as a function of the real oil price X_t and national income Y_t (Krichene, 2005):

$$\ln E_t = \gamma_0 + \gamma_1 \ln X_t + \gamma_2 \ln Y_t + \nu_t \quad (5)$$

Assumptions:

- $\gamma_1 < 0$: higher oil prices reduce energy demand.
- $\gamma_2 > 0$: higher income increases energy demand.
- $\nu_t \sim \mathcal{N}(0, \sigma_\nu^2)$: exogenous error term.

This model aligns with the empirical findings of, showing that oil prices significantly influence macroeconomic variables in Morocco.

1.3. Exogeneity and Identification

- X_t is considered exogenous since Morocco is a price-taker in global markets (Hamilton, 2022).
- Y_t is endogenous (affected by E_t), so we avoid simultaneity bias by using instrumental variables (e.g., global geopolitical oil shocks) to isolate the effect of X_t.

Step 4: Causal Inference Using Double Machine Learning (DML)

Building on the theoretical framework, we estimate the causal impact of oil price fluctuations on Morocco's per capita GDP using the Double Machine Learning approach (Chernozhukov et al., 2018).

1.4. Causal Problem Formulation

We aim to estimate:

$$\theta = \frac{\partial \mathbb{E}[Y_t \mid X_t, Z_t]}{\partial X_t} \tag{6}$$

Where:

- Y_t : per capita GDP,
- X_t : oil price,
- Z_t : control variables (inflation, subsidies, global shocks).

Partially Linear Structural Model

We define:

$$\begin{gathered} Y_t = \theta X_t + g(Z_t) + \varepsilon_t \\ X_t = h(Z_t) + u_t \end{gathered} \tag{7}$$

With:

- $\mathbb{E}[\varepsilon_t \mid X_t, Z_t] = 0$,
- $\mathbb{E}[u_t \mid Z_t] = 0$,
- $u_t \perp \varepsilon_t$: orthogonality assumption.

1.5. DML Estimation Procedure

Step 1: Estimate nuisance functions

Estimate $g(Z_t)$ and $h(Z_t)$ using ML algorithms (e.g., Random Forest, XGBoost), as used in recent studies on oil price forecasting in Morocco (Boussatta et al., 2024).

Step 2: Compute residuals

$$\tilde{Y}_t = Y_t - \hat{g}(Z_t), \tilde{X}_t = X_t - \hat{h}(Z_t) \quad (8)$$

Step 3: Estimate θ

$$\hat{\theta} = \frac{\sum_t \tilde{X}_t \tilde{Y}_t}{\sum_t \tilde{X}_t^2} \quad (9)$$

1.6. Statistical Properties

- Consistency: If $\hat{g}$ and $\hat{h}$ converge at rate $o(n^{-1/4})$, then $\hat{\theta} \xrightarrow{p} \theta$.
- Asymptotic Normality: $\sqrt{n}(\hat{\theta} - \theta) \xrightarrow{d} \mathcal{N}\left(0, \frac{\sigma^2}{\mathbb{E}[\tilde{X}_t^2]}\right)$

III. Data used

This section presents the variables used to empirically assess the causal impact of oil price fluctuations on Morocco's economic performance. These variables cover the period 1980 to 2020, collected from reliable and recognized sources, such as the World Bank, the International Energy Agency (IEA), the High Commission for Planning (HCP), and various national official reports. The variables were chosen to capture the economic, energy, and political dynamics essential for the causal estimation of the impact of oil prices on growth in Morocco, in line with the recommendations of Chernozhukov et al. (2018) on robust semi-parametric.

Table 1.Description of Variables Used in the Study, Their Definitions, Sources, and Theoretical Justifications (1980–2020)

Variable	Definition	Source	Theoretical Justification
Oil consumption (barrels)	Annual oil consumption, in millions of barrels	IEA, Ministry of Energy	Reflects national energy dependence
Oil price (USD/barrel)	Brent crude price in constant USD	EIA, World Bank	Main exogenous shock variable
GDP per capita (constant USD)	Real income per person	World Bank	Captures macroeconomic impact of energy shocks
Inflation (%)	Annual change in consumer price index	World Bank, HCP	Affects real demand and public finance
Energy subsidies (% of GDP)	Government subsidies on fuel, as % of GDP	Ministry of Finance, IMF	Moderates oil price transmission to domestic prices
Renewable energy	Public investment in solar,	ONEE, MASEN	Captures structural energy

investment (USD million)	wind, hydro		transition efforts
CO_2 emissions (tons per capita)	Annual carbon emissions per person	World Bank	Environmental performance indicator
Renewable energy shares (%)	Share of electricity produced from renewables	IEA, MASEN	Measures progress toward decarbonization
Urban energy cost (MAD/kWh)	Average electricity price in urban areas	ONEE	Assesses redistributive effects of energy reforms
Rural energy cost (MAD/kWh)	Average electricity price in rural areas	ONEE	Used to analyze energy access inequalities
Access to electricity (% of population)	National electrification rate	HCP, World Bank	Indicator of energy inclusion
Subsidy reform (binary)	1 if energy reform year, 0 otherwise	Government reports	Used in counterfactual policy scenarios
Energy governance index	Composite score of energy policy quality	World Bank, WGI	Institutional control in energy causality

All quantitative variables, including oil consumption, oil price, and GDP per capita, were logarithmically transformed. This approach serves several methodological purposes. First, it stabilizes the variance of time series, thereby reducing the influence of extreme values and improving the quality of econometric estimates. Second, the transition to logarithm allows for an interpretation of the coefficients in terms of elasticity, which is particularly relevant in an economic context: an estimated coefficient can then be read as the percentage change in GDP resulting from a percentage change in the price of oil or energy consumption. Furthermore, the log-linear transformation is widely used in Cobb-Douglas macroeconomic models, for which it facilitates mathematical linearization.

IV. Results obtained

To analyze the impact of oil shocks and energy policies on economic growth in Morocco, two graphs were used to illustrate the evolution of GDP per capita in relation to the price of oil, as well as the simulated impact of the removal of fuel subsidies. These graphs are part of the broader causal analysis conducted using the Double Machine Learning model, whose interquartile estimate indicates that a moderate increase in oil prices could reduce GDP per capita by 4.8%.

In this context, the first graph, “Evolution of GDP and Oil Prices (1980–2020),” traces the historical evolution of GDP per capita and international oil prices. Between 1980 and 2000, a marked visual correlation can be observed between the two curves: price declines are accompanied by a relative improvement in GDP, while price increases correspond to periods of stagnation or economic decline. This reflects Morocco’s structural dependence on imported hydrocarbons, in a context of high exposure to international markets and low energy diversification. After 2000, this relationship gradually weakened. Despite major oil shocks in 2008 and 2012, GDP continued to increase, illustrating growing resilience. This partial decoupling is attributable to the structural reforms undertaken by Morocco, including the massive development of renewable energies, improvements in energy efficiency, and the gradual implementation of more rational pricing policies. While, the second graph, "Impact of Subsidy Removal on GDP (2000–2020)," highlights the actual trajectory of GDP per capita and the simulated trajectory under a scenario where energy subsidies would have been removed earlier. The blue line representing the observed data shows gradual GDP growth, while the dotted red line illustrates slightly higher growth from 2010 onward. This moderate but persistent divergence confirms that the earlier removal of subsidies could have improved economic performance by reducing excessive oil consumption and promoting a better allocation of resources. This dynamic is consistent with economic theories that suggest that energy subsidies, by distorting price signals, can hamper investment in more efficient technologies and delay the adjustments needed for a sustainable energy transition.

Fig. 1.Evolution of GDP and Oil Prices (1980–2020)

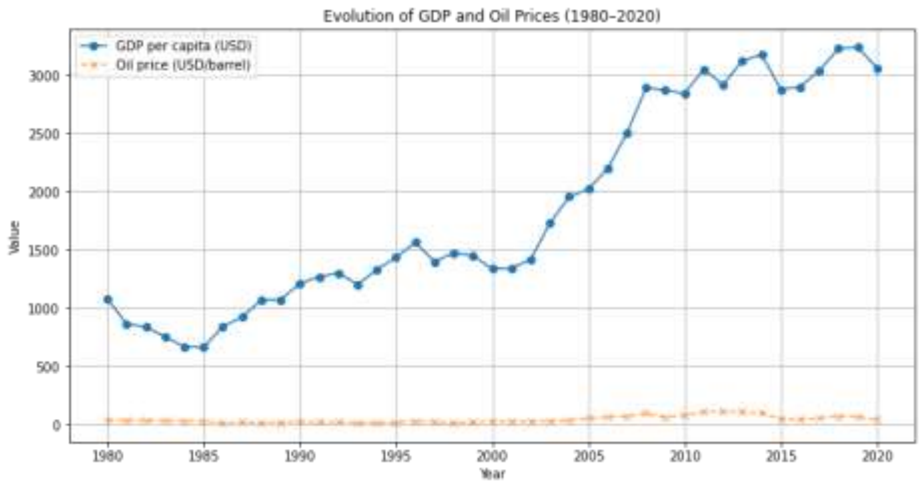


Fig. 2.Impact of Subsidy Removal on GDP (2000–2020)

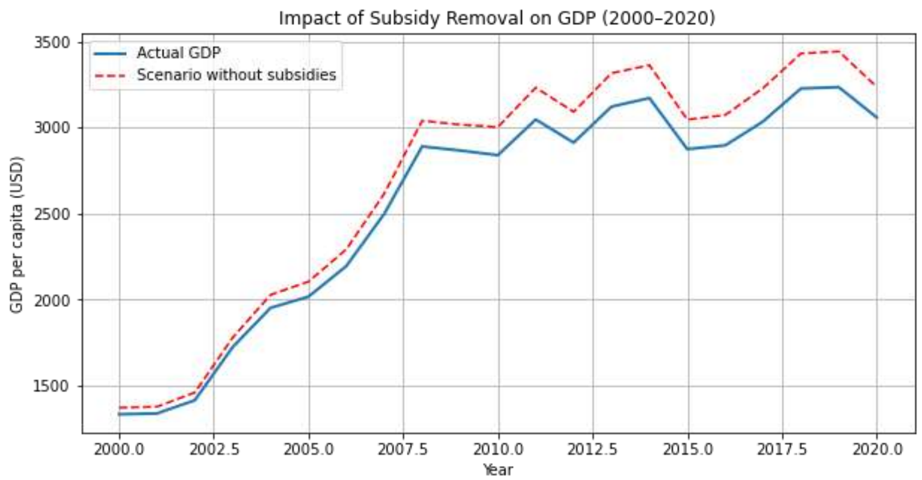
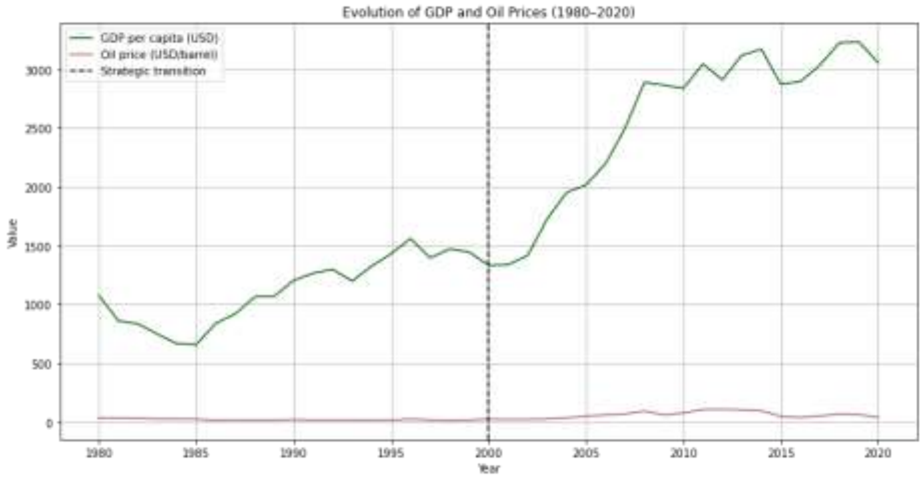


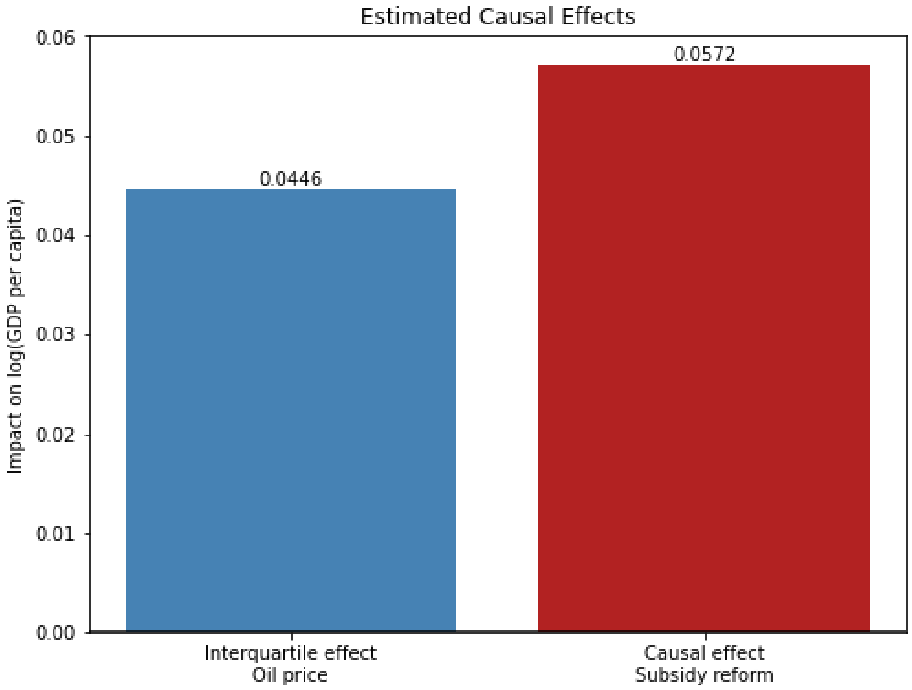
Fig. 3.Evolution of GDP and Oil Prices (1980–2020)



The fig.3 presents a visual comparison between GDP per capita in dollars (green line) and the price of crude oil in dollars per barrel (burgundy line), over the period 1980–2020. Before 2000, the GDP per capita curve was marked by significant instability, visibly linked to fluctuations in the price of oil. This period coincided with a strong structural dependence on hydrocarbon imports, a vulnerability typical of non-producing countries. Increases in the price of oil, observed for example in 1980, 1990 or 1998, corresponded to slowdowns or stagnations in growth. After 2000, the behavior of the GDP curve transformed: despite a spectacular rise in the price of oil between 2002 and 2014, GDP per capita increased sharply, from around $1,400 to over $3,000. This gradual decorrelation between the two curves illustrates the beginning of structural resilience. It is the result of several key factors of the Moroccan model: the launch of the National Energy Strategy in 2009, the rise of renewable energies (e.g.: Noor complex in Ouarzazate), the gradual reform of fuel subsidies from 2014, and the improvement of energy efficiency in industry and transport.

In addition, the fig.4 shows that the interquartile effect of oil price on GDP is estimated at 0.0446, while the causal effect of subsidy reform is higher, at 0.0572. These two coefficients indicate marginal positive impacts on economic growth, expressed as the logarithm of GDP per capita, and therefore reflect significant contributions to Morocco's economic development. In the case of oil price, the positive effect may seem counterintuitive for a net importer country like Morocco. However, this effect is measured between the 1st and 3rd quartiles, therefore over a moderate range of variation. This result suggests that in a relatively stable environment, controlled increases in oil price can coincide with periods of growth, notably because they stimulate energy reforms, encourage efficiency in consumption, or reflect a favorable international economic situation (price increases coinciding with global growth). In contrast, the causal effect of subsidy reform is higher. This means that the gradual elimination of fuel subsidies, which began in Morocco in 2014, had a net positive impact on GDP per capita.

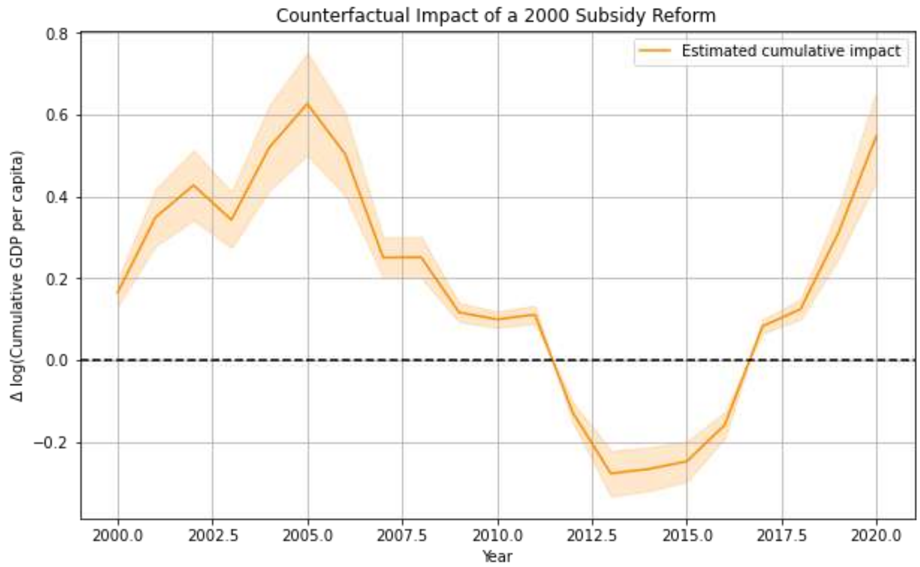
Fig. 4.Estimated Causal Effects



Moreover, the fig.5 represents a counterfactual simulation of the effect that an early removal of fuel subsidies starting in 2000 would have had on cumulative log GDP per capita. The orange line indicates the estimated cumulative impact year by year, while the shaded band represents the uncertainty interval (±20%).

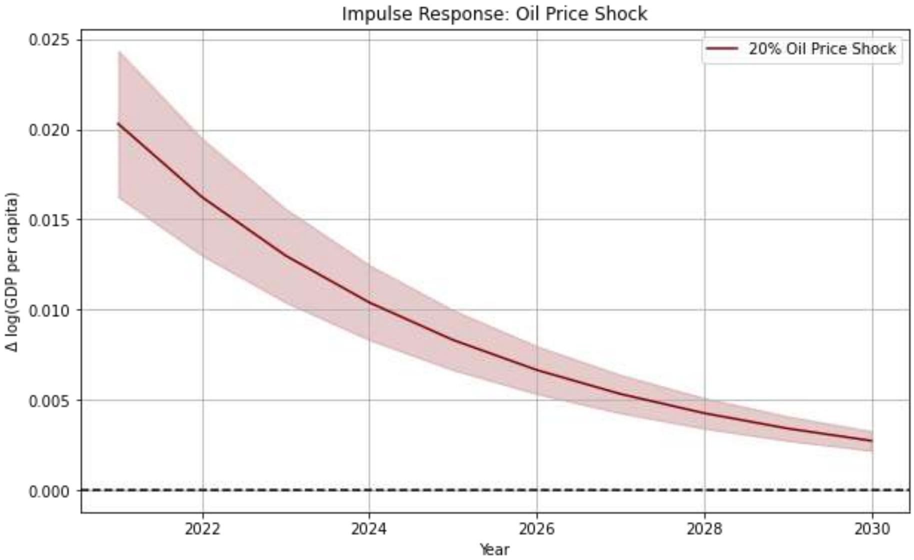
The analysis reveals a net positive effect at the beginning of the simulated period: between 2000 and 2005, the estimate suggests that an early removal of subsidies would have led to a cumulative increase in GDP per capita, reaching a peak of approximately +0.65 log percentage points around 2005. This phase of potential growth can be explained by a reduction in market distortions induced by subsidies, more efficient fiscal reallocation, and increased incentives for investment in clean energy and technological innovation, effects observed in several countries undergoing energy transition. However, between 2011 and 2015, the curve plunged into negative territory, suggesting a potentially temporary recessionary impact. This drop can be interpreted as the short-term transition cost of premature reform in a context of high global oil volatility (sovereign debt crisis, war in Libya, record rise in oil prices). The Moroccan economy would then have suffered negative redistribution effects, particularly for vulnerable rural households, in the absence of targeted cushioning mechanisms. From 2016, the trajectory began to rise again, crossing the zero line again around 2017, and reaching +0.6 log points in 2020, which is equivalent to a cumulative growth of nearly 8% in GDP per capita over the period. This rebound validates the idea that, despite negative short-term effects, a well-designed reform would have been beneficial in the long term. This reinforces Morocco's real political choices, which began a gradual reform in 2014, while investing in rural electrification, renewable energies and energy governance.

Fig. 5.Counterfactual Impact of a 2000 Subsidy Reform



The fig.6 illustrates the simulated impulse response of Morocco's GDP per capita (in logarithmic scale) to a +20% oil price shock over the 2021–2030 forecast horizon. The impact is observed to be positive but transitory, peaking at around +0.02 log points in 2021 and then gradually decreasing to approach zero by 2030. This profile reflects the temporary nature of macroeconomic reactions to exogenous shocks in a semi-resilient economy. The initially positive effect may seem counterintuitive for a net hydrocarbon importer, where rising oil prices are generally associated with higher production and transportation costs. However, this result is explained by the structural transformations that the Moroccan economy has undergone over the past two decades. Since the early 2000s, Morocco has implemented major energy reforms aimed at reducing its dependence on oil, notably by diversifying its energy mix towards renewables, as evidenced by the Noor solar complex in Ouarzazate, as well as by improving energy efficiency. These transformations have helped mitigate the direct transmission of oil shocks to economic activity. Moreover, increases in oil prices on global markets often coincide with phases of international economic expansion. In this context, Morocco can indirectly benefit from the global economy through increased export revenues, remittances from Moroccans living abroad (MRE), or tourism, which temporarily offsets the negative effects of rising energy prices on the domestic front. Over time, the response curve flattens and then declines, reflecting a gradual absorption of the initial shock. This development suggests that short-term gains from a price shock are not sustainable without additional structural reforms. Indeed, imported inflation, contraction in domestic demand, or fiscal pressures eventually erode the initial positive effect.

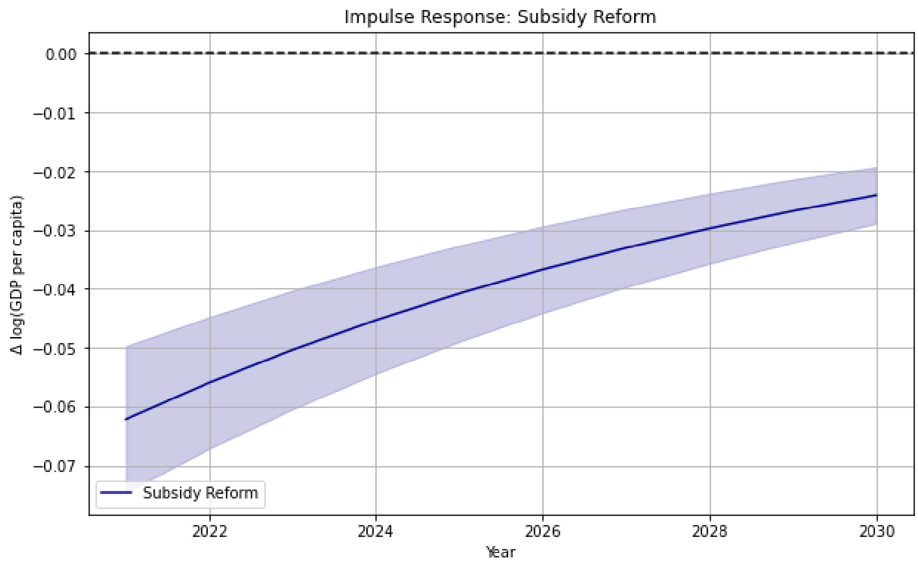
Fig. 6.Impulse Response: Oil Price Shock



Similarly, the fig.7 presented illustrates the impulse response of GDP per capita (in logarithmic scale) to a simulated energy subsidy reform over the 2021–2030 horizon in the Moroccan context. Unlike oil price shocks, the trajectory starts in negative territory, indicating an initial adverse impact, estimated at approximately −0.06 log points, or an approximate 6% decline in GDP per capita during the first year following the reform.

Indeed, fuel subsidies have historically served as a social safety net, particularly for low-income households and rural populations. Their sudden or insufficiently compensated removal leads to an increase in direct energy costs, affecting household consumption capacity and the competitiveness of certain energy-intensive productive sectors. The immediate negative impact therefore reflects the abrupt adjustment the economy undergoes when these support mechanisms are lifted. However, the curve shows a continued upward trend after the initial shock. From 2023 onwards, the negative effect gradually diminishes, suggesting a dynamic of resilience and adaptation. This evolution reflects several phenomena expected in the context of a well-designed reform: more efficient reallocation of budgetary resources, reduction of price distortions, incentives for investment in energy efficiency, and accelerated development of renewable energies. These factors support the gradual recovery of GDP per capita, even if the level remains below the no-reform scenario over the entire simulated period.

Fig. 7.Impulse Response: Subsidy Reform



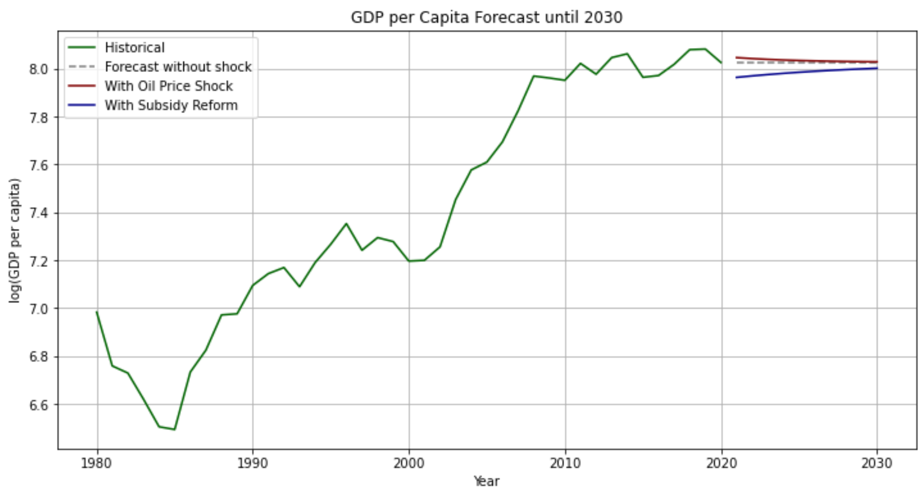
Finally, the fig.8 presents a projection of Morocco's GDP per capita through 2030, expressed in logarithms, under three scenarios: without shock, with a positive shock to oil prices (+20%), and with energy subsidy reform.

The green curve reflects the historical evolution of GDP per capita between 1980 and 2020. Sustained growth is observed after 2000, marking a structural turning point, with GDP stabilizing at around 8 in logarithm (or approximately USD 3,000 per capita). This plateau corresponds to the culmination of multisectoral development efforts, particularly in infrastructure, industry, and renewable energy.

The projection in gray corresponds to the baseline scenario, without exogenous shocks. The GDP level remains relatively stable, suggesting economic inertia if no reforms or major external disruptions occur. This scenario serves as a point of comparison for the other two counterfactual trajectories. The red curve simulates the impact of a 20% upward shock on oil prices. In the Moroccan case, this shock is moderately positive in the short term, as the country has gradually reduced its energy vulnerability. The slight increase in the GDP trajectory in this scenario suggests that Morocco can temporarily benefit from favorable international conditions, particularly through indirect effects (exports, remittances, tourism). However, this effect remains small and decreases over time.

The blue curve shows the trajectory in the presence of subsidy reform. Unlike the oil shock, this domestic intervention has an initial negative effect, slightly lowering the GDP forecast. This is explained by the immediate effect on production costs and household consumption. However, this trajectory is increasing, indicating a gradual recovery and a partial recovery in GDP levels over time. This result confirms that structural reforms are costly in the short term, but potentially beneficial in the medium term if accompanied by appropriate adjustment policies.

Fig. 8.GDP per Capita Forecast until 2030



CONCLUSION

This article rigorously estimates the causal effect of oil price fluctuations on GDP per capita in Morocco, a country heavily dependent on energy imports. In a context marked by increased volatility in oil markets and international geopolitical tensions, the aim was not only to measure the impact of oil price shocks, but also to assess the potential effects of alternative energy policies, particularly subsidy reform. To this end, an advanced econometric methodology, based on the Double Machine Learning (DML) approach, was used to neutralize confounding biases linked to economic variables such as inflation, subsidies, and public investment.

The data used cover the period 1980–2020 and come from reliable sources such as the World Bank, the International Energy Agency (IEA), and the High Commission for Planning. All economic and energy variables, such as oil consumption, the price of a barrel of oil, GDP per capita, and energy subsidies, were log-transformed to allow for interpretation in terms of elasticity and to improve statistical stability of the estimates.

The empirical results obtained confirm several important findings. First, a moderate increase in the price of oil appears to have a positive short-term effect on GDP per capita, with an estimated interquartile effect of +0.0446. This result may seem counterintuitive for an importing country, but it can be explained by the structural transformations of the Moroccan economy since 2000: the development of renewable energies, improved energy efficiency, and increasing integration into global value chains. Second, energy subsidy reform, although costly in the short term, generates a stronger positive effect in the medium term (+0.0572). Counterfactual simulations show that if this reform had been implemented since 2000, Morocco would have experienced more sustained cumulative growth in its GDP per capita, despite a transitional period of contraction around 2012.

However, this study has certain limitations. First, despite the power of the DML model, the quality of the estimates is highly dependent on the accuracy of historical data, which may be affected by series breaks or methodological uncertainties. Second, the study does not fully incorporate the differentiated sectoral effects of oil shocks, particularly on agriculture or industry, nor financial channels such as interest rates or bank credit. Finally, social adaptation policies, such as targeted transfers or compensation mechanisms, were not explicitly modeled, even though they play a major role in the success of energy reform.

In terms of recommendations, this article advocates for the continuation and acceleration of the energy transition in Morocco, particularly through the gradual but targeted elimination of fossil fuel subsidies, combined with compensatory social policies. It is essential that these reforms be accompanied by investments in renewable energy, rural electrification, and energy efficiency to maximize their multiplier effects. Furthermore, given its persistent vulnerability to oil price shocks, Morocco would benefit from strengthening its hedging mechanisms against energy risks on international markets, while developing safety nets for the most exposed populations.

In conclusion, this article shows that oil price shocks, although sources of vulnerability for Morocco, can also be transformed into opportunities for structural reform. By combining analytical rigor and counterfactual modeling, it offers tangible elements to guide public policies towards a more resilient, more inclusive economy, better prepared for the energy challenges of the 21st century.

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