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Sarah Nandnaba
Ecole normale superieure (ENS) Paris-Saclay
Abebe Hailemariam
Curtin University Perth
Rangan Gupta
University of Pretoria
Xin Sheng
Anglia Ruskin University

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Department of Economics
University of Pretoria
0002, Pretoria
South Africa
Tel: +27 12 420 2413

A Note on Oil Consumption and Growth: The Role of Greenhouse Gases Emissions

Sarah Nandnaba[*] Abebe Hailemariam [†] Rangan Gupta[‡] Xin Sheng [§]

Abstract. The paper empirically examines the role of Greenhouse Gases (GHGs) emissions on the oil consumption-growth nexus of sixteen OECD countries. Using a nonlinear local projection approach and a long historical dataset from 1890 to 2022, we find that the impact of oil consumption on economic growth is conditional on the categorization of the countries based on the level of GHGs emissions. More specifically, we find that economies under the high-emission category face a slowdown in growth, while those in low-emission group can benefit from a positive shock in oil consumption, especially in the post World War II era. The results have important policy implications for sustainable growth.

Keywords: Oil consumption; economic growth; sustainability; climate change; greenhouse gases emissions; nonlinear local projection. JEL classification: Q43, Q53

1 Introduction

When implementing climate change mitigation measures, a concern arises regarding the potential reduction in economic growth. This concern stems from the fact that energy usage, a crucial production input, also generates Greenhouse Gases (GHGs) emissions, thus impacting environmental quality. In this context, policymakers promote energy conservation to protect the environment, which may reduce economic growth. GHGs emissions adversely affect growth, suggesting that improved energy management could enhance growth rather than hinder it.

The study aims to evaluate the extent to which oil consumption affects growth, conditional on the level of GHGs emissions. By directly measuring the negative impact of higher GHGs emissions from energy consumption on growth, the paper seeks to provide evidence supporting policies for better energy management and reduction of GHGs emissions.

The underlying hypothesis is that GHGs emissions can positively and negatively affect growth. GHGs emissions arising from energy combustion contribute to environmental degradation, while being positively associated with growth. On the one hand, GHGs emissions are one of the main factors in climate change, as highlighted in Baethgen (2010). The increase in GHGs emissions has a detrimental effect on climate, negatively affecting economic growth, especially when a certain limit of climate change is crossed. In this regard, using a neoclassical stochastic production function, Alagidede et al. (2016) shows that climate risk dampens per capita economic growth beyond a certain threshold of temperature and precipitation. GHGs emissions can downgrade the environmental quality and negatively affect economic growth. However, the effect is still indirect and measured through the environment rather than on growth itself. This methodology might be subject to bias since the negative effect can change alongside the chosen environmental quality

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[*] Department of Economics, École normale supérieure (ENS) Paris-Saclay, 91190 Gif-sur-Yvette, France. Email: sarah.nandnaba@ens-paris-saclay.fr.

[†] Bankwest Curtin Economics Centre, Faculty of Business and law, Curtin University Perth, 6102, Australia. Email: abebe.hailemariam@curtin.edu.au.

[‡] To whom correspondence should be addressed. Department of Economics, University of Pretoria, Pretoria, 0002, South Africa. Email: rangan.gupta@up.ac.za.

[§] Lord Ashcroft International Business School, Anglia Ruskin University, Chelmsford, United Kingdom. Email: xin.sheng@anglia.ac.uk.

index and its associated weight on economic growth. On the other hand, GHGs emissions are positively associated with growth. Using a total factor productivity (TFP) index, Kalaitzidakis et al. (2018), examine the relationship between TFP growth and emissions. They found a positive relationship between GHGs emissions and economic development. Their model includes an energy input, which is the driving force of GHGs emissions. GHGs emissions stem from energy consumption and are a by-product of the production process. Consequently, the increase in energy use, which positively contributes to growth, creates GHGs emissions. While they contribute to climate change, those emissions are still positively related to growth. From those insights, nonlinear effects of GHGs emissions on growth arise. Environmental degradation due to GHGs emissions is detrimental to growth, while GHGs emissions stemming from energy consumption increase with economic activity.

The effect of oil consumption, as well as CO_2 emissions, on economic growth, has been widely assessed in the literature (see, for example, Mardani et al. (2019); Adekoya (2021); Agboola et al. (2021) for detailed reviews). However, no studies have measured the nonlinear effect, conditional on the level of GHGs, emphasizing the need for energy consumption control. Assessing the direct effect of GHGs emissions on growth would be a way to go one step further in supporting climate mitigation. Indeed, it would enhance the weak sustainability arguments, stating that continued growth is incompatible with environmental sustainability. By analyzing that GHGs emissions have a stronger adverse effect on countries that emit more, i.e., those who consume more pollutive energy, one can state that GHGs emissions dampen the environment and cause a decline in economic growth.

To examine the nonlinear effect of GHG(s) emissions on the nexus between oil consumption and growth, we employ a regime-based local projections model proposed by Jordà et al. (2020). This approach allows for estimating the effect of an oil shock on growth while differentiating the regimes by the level of carbon dioxide (CO_2) emissions to assess whether higher GHGs emissions harm growth. The study covers a panel of sixteen Organisation for Economic Co-operation and Development (OECD) countries between 1890 and 2022. The findings reveal that oil consumption nonlinearly impacts growth conditional on the level of GHGs emissions. Specifically, we find that for countries falling in the low-emission regime oil consumption can promote growth, but there is an adverse effect on growth for the economies in the high-emission regime, suggesting that policies to mitigate CO_2 emission have a win-win effect on growth and the environment.

The remainder of the paper is organized as follows: Section 2 presents the data, while Section 3 presents the methodology involving a nonlinear local projection model in a panel setting. The empirical results part is contained in Section 4. Finally, Section 5 concludes the paper.

2 Data

Different datasets are used to assess the possible slowdown effect of CO_2 emissions on oil consumption-driven growth of Gross Domestic Product (GDP) per capita. Data on real GDP per capita, labor productivity, and capital intensity are obtained from Bergeaud et al. (2016). Capital intensity, i.e., total capital divided by the number of hours worked, and labor productivity, which is gross labor divided by hours worked, are used as control variables in the model. The level of CO_2 emissions due to oil consumption is chosen from Ritchie et al. (2023) database to account for GHGs emissions. Finally, oil consumption per capita, is derived from Bergeaud and Lepetit (2020). The complete dataset constitutes a long historical panel of data that covers sixteen OECD countries[1] from 1890 to 2022, with the countries and the sample period being driven by availability of data.

3 Methodology

To measure the potential effect of CO_2 emission on the growth-energy consumption relationship, the study measures the effect of an oil shock on growth while differentiating countries by the level of CO_2 emissions. The regimes-based impact of the oil consumption shock is computed through a nonlinear local projection model, following the methodology of Jordà et al. (2020).

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[1] Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland,, the United Kingdom, and the United States.

In the model, the switching variable is a dummy derived from the average of the time series of the cross-sectional average of CO_2 emissions. Countries emitting more (less) than this average are classified as high (low) GHGs emitters. This approach allows us to gauge the effect of GHGs emissions in shaping the nature of the nonlinear relationship between oil consumption and growth.

An endogeneity bias could arise when estimating the relationship between oil consumption on growth (Balcilar et al., 2010; Chang et al., 2015), therefore we obtain a measure of oil consumption shock recovered as the residuals from growth in oil consumption regressed on a lag of itself and economic growth in a panel data-setting as follows:

$$O_{i,t} = O_{i,t-1} + Y_{i,t} + \alpha_i + \mu_t + e_{i,t} \tag{1}$$

where $O_{i,t}$ is the growth of oil consumption per capita, $O_{i,t-1}$ is the first lag of growth of oil consumption per capita, $Y_{i,t}$ is GDP per capita growth, used as controls. α_i and μ_t are country and time fixed effects respectively. $e_{i,t}$ is the residuals, which will be used as the shock variable in the nonlinear local projection model.

The main model of interest, following Jordà et al. (2020) is given by:

$$\begin{aligned} Y_{i,t+s} = (1 - D_t)\Big[\delta_{i,s}^{High} + \beta_s^{High} Y_{i,t} + \lambda_s^{High} e_{i,t} + \gamma_s^{High} X_{i,t}\Big] \\ + D_t\Big[\delta_{i,s}^{Low} + \beta_s^{Low} Y_{i,t} + \lambda_s^{Low} e_{i,t} + \gamma_s^{Low} X_{i,t}\Big] + \epsilon_{i,t+s} \end{aligned} \tag{2}$$

$$D_t = \begin{cases} 1 & \text{if } \frac{1}{T}\sum_{t=1}^{T} \mathrm{CO2}_{i,t} < \frac{1}{N \cdot T}\sum_{i=1}^{N}\sum_{t=1}^{T} \mathrm{CO2}_{i,t} \\ 0 & \text{if else} \end{cases} \tag{3}$$

$Y_{i,t+s}$ is the growth of GDP per capita for the country i at time t, and s is the forecast horizon (which we at ten years). D_t is the switching dummy variable based on the average of the time series of the cross-sectional average of CO_2 emissions. It takes the value of 1 for low-regime i.e., countries whose average time series emissions are less than the abovementioned average, and takes 0 otherwise for high-emitters. $\delta_{i,s}$ is the regime-specific cross sectional fixed-effects, with β_s , λ_s, and γ_s correspond to the responses of economic growth one to ten-year-ahead due to values of economic growth, oil shock ($e_{i,t}$) and other control variables ($X_{i,t}$, i.e., capital intensity and labor productivity) at time t, for high- and low-emitters, given by the superfixes “High” and “Low”, respectively.[2]

4 Empirical findings

Figure 1 represents the impulse response functions of economic growth following a positive and exogenous oil consumption shock, with results in the left- panel corresponding to the high CO_2 emitters, and the right-panel for the relatively lower polluters. As is obvious, the impact on the countries falling under the high-emission regime are negatively impacted by the oil consumption shock, with the effect being statistically significant (given the 68% confidence bands) in an intermittent manner. As far as the low-emitters are concerned the effect is positive following an oil consumption shock, but is statistically significant over the horison of two- to four-year-ahead following the shock.

[INSERT FIGURE 1 HERE.]

Given that the only difference between these regimes is the underlying CO_2 emission levels of the countries, one plausible explanation for this different impact lies in the management of fossil fuel resources and

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[2] It must be realized that, CO_2 emission is a function of energy consumption, and countries emitting more (less) CO_2 tend to consume more (less) oil. Consequently, when estimating the nonlinear effect of an oil consumption shock on growth, high (low)-emission countries relying more (less) heavily on oil are likely to benefit more (less) from the positive shock. The high correlation between the two variables might affect the estimation and provide biased results, which we avert via the exogenous dummy variable that categorizes the countries into high and low-emitters in our nonlinear set-up, rather than using an interaction variable.

energy consumption. Thus, a regime having countries with lower GHGs emissions indicate more efficient oil management, as energy consumption significantly contributes to GHGs emissions. Indeed, the primary emission source is tied to oil and fossil fuel combustion, which, in turn, is identified as the main factor of environmental degradation (Thompson et al. (2017)). In Keçebaş et al. (2011), fossil fuels combustion is considered as the dominant cause of climate change because of its major CO_2 emissions.[3]. Thus, controlling energy consumption is the primary cost-effective way to prevent climate change and reduce GHGs emissions.[4] Naturally, better energy management and reduced oil consumption allow for alleviating the growth slowdown arising from feedback effects from GHGs emissions. Indeed, a positive oil shock may increase CO_2 emissions, leading to a feedback loop that negatively impacts economic growth. The negative effect on growth could be realized through the depreciation of capital stock and reduced labor productivity. Those effects are exacerbated by the high CO_2 polluting regimes of countries since their GHGs emission and oil dependence are already strong.[5]

To provide a time-varying nature to the study, especially given that rapid industrialization took place post the World War II, we repeated the analysis over two sub-samples of 1890–1945 and 1946–2022. As can be seen from Figures 2 and 3 corresponding to the first and second sub-samples, respectively, the positive effect of oil consumption on growth for the low-polluting countries primarily originates in a statistically significant manner in the post World War II era, especially over the medium to long-horizons. As far as the high-polluters are concerned, in general, the effects of oil consumption on economic growth has always been negative for these economies, though the adverse impact is relatively stronger over 1946–2022. Our findings tend to suggest that countries that have implemented technologies to keep in control the GHGs emissions generated from oil usage, have witnessed a positive effect on growth associated with energy consumption, but economies that have remained high-pollutes have started to be more strongly negatively impacted in terms of growth by consuming more oil.

[INSERT FIGURES 2 AND 3 HERE.]

5 Conclusion

To empirically assess the effect of CO_2 emissions on the nexus between oil consumption shock and economic growth rate, the study applied a nonlinear local projection method to long historical data from sixteen OECD countries spanning the period of 1890 to 2022. The model differentiated countries based on the level of CO_2 emissions and aimed to determine whether higher GHGs emissions lead to a more pronounced negative impact on growth following an oil consumption shock. The results indicate that the high-emission regime involving countries that are relatively higher polluters, tends to experience a slowdown in growth compared to the low-emission countries, which shows an improvement in economic growth following a positive shock to oil consumption, especially over 1946 to 2022. These findings suggest efficient resource management mitigates CO_2 emissions, supporting the initial hypothesis of our work. From these results, it is obvious that oil consumption can still be growth-enhancing, but would require lower GHGs emissions possibly associated with stringent regulation of energy combustion, but, in general, the transition to clean energy is paramount in the context of the energy-growth relationship.

As part of future research, it would be interesting to extend this analysis to larger set of both developed and developing countries.

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[3] According to the International Energy Agency (IAE), 34.4% of CO_2 emissions are due to oil consumption.

[4] For example, the IAE has drawn a Net Zero Emissions Scenario by 2050, which is a normative measure that promotes energy consumption management to achieve net zero CO_2 emissions by that date.

[5] Other explanations for the difference in effect could be also be drawn. First, the oil consumption shock is a demand shock, which can increase oil prices, further affecting economic growth by increasing the cost of production, especially for more oil-reliant, and hence, relatively higher polluting countries, wherein the firms in these economies could face challenges in swiftly adapting their production processes or transitioning to alternative (cleaner) energy sources by altering the "optimal" input-mix.

References

Adekoya, O. B. (2021). Revisiting oil consumption-economic growth nexus: Resource-curse and scarcity tales. *Resources Policy*, 70:101911.

Agboola, M. O., Bekun, F. V., and Joshua, U. (2021). Pathway to environmental sustainability: Nexus between economic growth, energy consumption, co2 emission, oil rent and total natural resources rent in saudi arabia. *Resources Policy*, 74:102380.

Alagidede, P., Adu, G., and Frimpong, P. B. (2016). The effect of climate change on economic growth: evidence from sub-saharan africa. *Environmental Economics and Policy Studies*, 18:417–436.

Baethgen, W. E. (2010). Climate risk management for adaptation to climate variability and change. *Crop Science*, 50:S–70.

Balcilar, M., Ozdemir, Z. A., and Arslanturk, Y. (2010). Economic growth and energy consumption causal nexus viewed through a bootstrap rolling window. *Energy Economics*, 32(6):1398–1410.

Bergeaud, A., Cette, G., and Lecat, R. (2016). Productivity trends in advanced countries between 1890 and 2012. *Review of Income and Wealth*, 62(3):420–444.

Bergeaud, A. and Lepetit, M. (2020). Research program CH.DUPIN, a short note. *Available at : http://longtermproductivity. com/chdupin/CHDUPIN. pdf.*

Chang, T., Gadinabokao, O. A., Gupta, R., Inglesi-Lotz, R., Kanniah, P., and Simo-Kengne, B. D. (2015). Panel granger causality between oil consumption and gdp: evidence from brics countries. *International Journal of Sustainable Economy*, 7(1):30–41.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2020). The effects of quasi-random monetary experiments. *Journal of Monetary Economics*, 112:22–40.

Kalaitzidakis, P., Mamuneas, T. P., and Stengos, T. (2018). Greenhouse emissions and productivity growth. *Journal of Risk and Financial Management*, 11(3):38.

Keçebaş, A., Alkan, M. A., and Bayhan, M. (2011). Thermo-economic analysis of pipe insulation for district heating piping systems. *Applied Thermal Engineering*, 31(17-18):3929–3937.

Mardani, A., Streimikiene, D., Cavallaro, F., Loganathan, N., and Khoshnoudi, M. (2019). Carbon dioxide (co2) emissions and economic growth: A systematic review of two decades of research from 1995 to 2017. *Science of The Total Environment*, 649:31–49.

Ritchie, H., Rosado, P., and Roser, M. (2023). CO2 and greenhouse gas emissions. *Our World in Data*. https://ourworldindata.org/co2-and-greenhouse-gas-emissions.

Thompson, T. M., Shepherd, D., Stacy, A., Barna, M. G., and Schichtel, B. A. (2017). Modeling to evaluate contribution of oil and gas emissions to air pollution. *Journal of the Air & Waste Management Association*, 67(4):445–461.

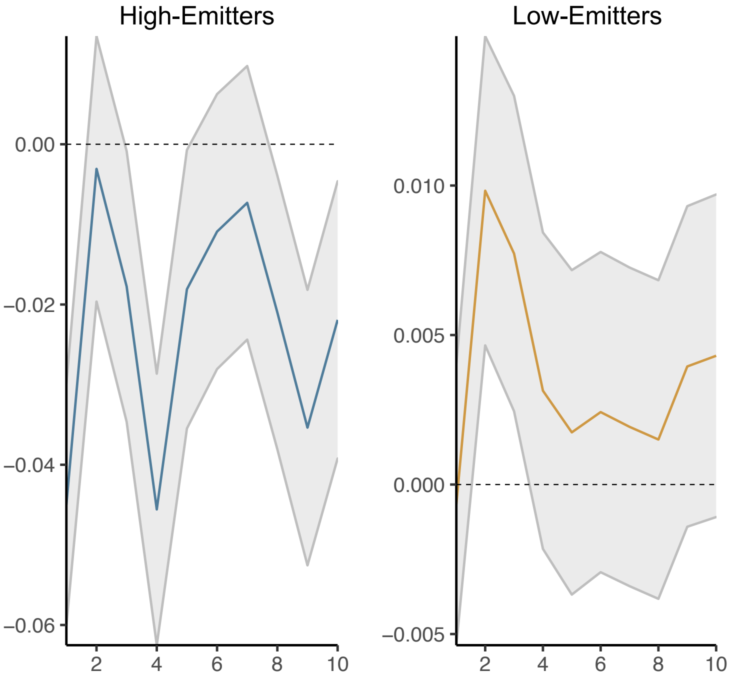

Figure 1: Effects of Oil Consumption Shock on Economic Growth: 1890–2022

Figure 2: Effects of Oil Consumption Shock on Economic Growth: 1890–1945

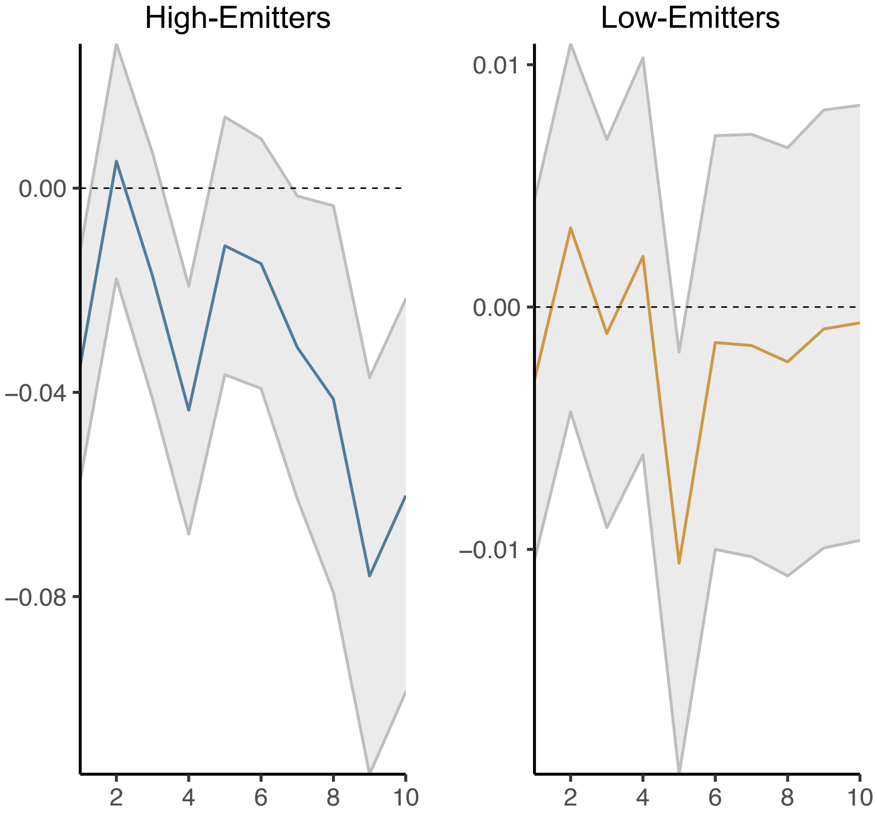

Figure 3: Effects of Oil Consumption Shock on Economic Growth: 1946–2022