Green Infrastructure, Energy Transition, and Carbon Pricing in Morocco: A GTAP-E CGE Analysis.

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Energy transition and the reduction of greenhouse gas emissions have become major global challenges, in a context marked by the continuous increase in energy demand and growing constraints related to climate change (IPCC, 2022; IEA, 2023). The energy sector accounts for more than 70% of global CO_2 emissions, while current energy consumption trajectories remain incompatible with international climate targets (IPCC, 2022). Recent estimates indicate that annual investments required in green infrastructure—including renewable energy, energy efficiency, and low-carbon transport—would need to exceed USD 4 trillion by 2030 in order to ensure a sustainable energy transition (IEA, 2023). In this context, public investment is widely recognized as a central lever for steering energy systems toward less carbon-intensive pathways and for accelerating structural transformation of economies (OECD, 2021; UNEP, 2022).

These challenges are particularly acute in emerging economies, where economic growth remains closely tied to energy consumption and where reliance on energy imports increases exposure to external shocks. Morocco represents a relevant case, as its economy has long been characterized by high energy dependence, with imports covering more than 90% of domestic energy needs, placing structural pressure on the trade balance and increasing vulnerability to international energy price volatility (World Bank, 2018; IEA, 2020). This dependence has been accompanied by relatively high energy intensity and a concentration of CO_2 emissions in a limited number of sectors, notably industry, electricity generation, and transport.

In response, Morocco has gradually implemented a national strategy for energy transition and sustainable development aimed at reducing external energy dependence, improving energy efficiency, and limiting greenhouse gas emissions (Ministry of Energy Transition and Sustainable Development, 2020). This strategy has been supported by substantial public investment in renewable energy through flagship projects such as the Noor Ouarzazate solar complex and major wind farms, as well as by investments in energy infrastructure modernization and sustainable transport, including the Al Boraq high-speed rail network (MASEN, 2021; ONCF, 2019). These efforts have been complemented by international financing programs, such as the Climate II program supported by the German Development Bank (KfW), and are embedded within the broader framework of the New Development Model and the National Sustainable Development Strategy (Special Commission on the Development Model, 2021).

Despite the scale of these investments, their macroeconomic and environmental impacts remain insufficiently assessed. Green infrastructure and energy efficiency measures simultaneously affect

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production structure, energy demand, external trade, and CO_2 emissions, generating economy-wide interactions that cannot be fully captured by partial or sectoral analyses (Böhringer and Rutherford, 2002; Wing, 2004). Accordingly, this study examines the extent to which green infrastructure investments under Morocco's national strategy contribute to reducing energy intensity and CO_2 emissions while preserving macroeconomic balances, addressing the following research question: **what are the economy-wide macroeconomic and environmental effects of green infrastructure investment in Morocco within an integrated framework that accounts for interactions between energy, production, and external trade?**

Literature Review

The economic literature identifies public infrastructure as a key driver of productivity and economic growth by improving the productive environment and reducing production and transaction costs (Arrow and Kurz, 1970). This role has been formalized in endogenous growth models, which show that public investment can durably influence growth trajectories through its effects on private capital accumulation (Romer, 1986; Lucas, 1988; Barro, 1990). Empirical evidence generally supports a positive relationship between infrastructure and growth, although the magnitude of the effects depends on infrastructure type and quality (Aschauer, 1989; Calderón and Servén, 2010).

Since the 1990s, this relationship has increasingly been reframed in the context of energy and climate challenges. Environmental economics highlights greenhouse gas emissions as a global externality requiring integrated and long-term policy responses (Pearce et al., 1989; Nordhaus, 1991), while climate–economy analyses emphasize the need to jointly assess energy systems, technological change, and productive structure to evaluate emissions trajectories and macroeconomic impacts (Nordhaus, 1994; Stern, 2007; IPCC, 2007). Within this perspective, green infrastructure—defined as public investment in renewable energy, energy efficiency, and low-carbon technologies—is viewed as a central instrument of the energy transition (OECD, 2011; UNEP, 2012; OECD, 2021).

The complexity of interactions between energy, the environment, and the economy has motivated the use of integrated modeling frameworks. Computable general equilibrium (CGE) models provide a benchmark tool for policy analysis by capturing intersectoral linkages, relative price adjustments, and resource constraints (Shoven and Whalley, 1972). Energy–environment extensions of CGE models and broader Energy–Economy–Environment (E3) frameworks have been widely applied to assess climate and energy policies (Jorgenson and Wilcoxen, 1990; Barker et al., 2006; IPCC, 2014). In this context, the GTAP-E model represents a major advancement by explicitly incorporating energy use and CO_2 emissions within a multi-regional CGE framework (Burniaux and Truong, 2002; McDougall and Golub, 2007).

While empirical applications using these models generally find that green investment and climate policies reduce energy intensity and emissions, their macroeconomic effects depend on initial structural conditions (Böhringer and Rutherford, 2002; Pollitt, 2019). For emerging economies, including Morocco, economy-wide analyses remain relatively scarce. Existing studies mainly focus on public investment, growth, or renewable energy using partial or aggregate approaches (IEA, 2010; World Bank, 2014), leaving the joint assessment of green infrastructure, energy consumption, and CO_2 emissions insufficiently explored. This gap motivates the use of an integrated Energy–Economy–Environment general equilibrium framework in the present study.

Methodology and Simulations

The analysis is based on a computable general equilibrium (CGE) model that explicitly integrates interactions between economic activity, energy markets, and CO_2 emissions. The analytical framework follows energy–environment extensions of CGE models and represents an open economy composed of multiple production sectors, households, a government, and the rest of the world, linked through markets for goods, factors, and energy. Sectoral production is modeled using nested CES functions that allow substitution between primary factors, intermediate inputs, and different energy sources. CO_2 emissions are directly linked to the use of fossil energy through fixed emission coefficients and are incorporated into the model through proportional relationships between fossil energy consumption and emissions.

The model is calibrated using the GTAP Data Base, version 10, which provides a consistent global representation of production, consumption, international trade, and energy accounts. For Morocco, the reference year is 2019, corresponding to an equilibrium situation of the economy prior to recent shocks. This benchmark equilibrium serves as the reference scenario against which all policy simulations are evaluated.

Simulations are conducted using a counterfactual approach, whereby energy and climate policy shocks are introduced and the resulting equilibria are compared to the reference case. The objective is to assess how different energy policy mechanisms affect energy intensity, CO_2 emissions, the productive structure, and overall economic growth relative to a no-policy scenario.

The reference scenario reproduces the Moroccan economy in 2019 and serves as the baseline for comparison. The first policy scenario introduces an exogenous improvement in energy efficiency in productive sectors. This is implemented as a reduction in energy input coefficients within sectoral production functions, implying that a lower quantity of energy is required to produce a given unit of value added. This choice reflects the economic effects of green infrastructure investment, such as modernization of energy networks, reduced losses, and improved equipment performance.

The second policy scenario combines energy efficiency improvements with a shift in the energy mix toward less carbon-intensive sources. This transformation is captured by increasing substitution possibilities between different energy inputs within production and consumption functions, thereby representing energy diversification and the gradual expansion of renewable energy. This variable is selected to reflect structural changes in the energy system associated with national energy transition strategies.

The third policy scenario introduces a carbon tax applied to CO_2 emissions. The tax is modeled as a proportional levy on emissions generated by fossil energy use, which raises the effective cost of carbon-intensive inputs. This mechanism provides incentives for economic agents to reduce fossil energy consumption, adjust production choices, and adopt cleaner technologies. The choice of this variable is motivated by the central role of carbon pricing as a policy instrument for internalizing environmental externalities and guiding decarbonization.

A final scenario combines energy efficiency improvements with the carbon tax in order to assess the complementarity between green infrastructure investment and carbon pricing. This scenario allows an evaluation of whether energy efficiency gains can mitigate the economic costs associated with carbon constraints and facilitate the adjustment of the economy toward a low-emissions trajectory.

Simulation outcomes are interpreted as deviations from the reference scenario, enabling the identification of both individual and combined effects of the different energy policy instruments on the Moroccan economy.

Preliminary Results

Simulation results indicate differentiated impacts of energy policy instruments on the Moroccan economy relative to the 2019 baseline. Improvements in energy efficiency reduce economy-wide energy intensity by 4–6% and CO_2 emissions by 3–5%, while supporting economic activity, with real GDP increasing by 0.3–0.6% and energy imports declining by 4–7%. When combined with a shift toward a less carbon-intensive energy mix, emission reductions are amplified (6–9%), energy intensity falls by 5–7%, and GDP gains remain positive though more moderate (0.2–0.4%) due to adjustment costs.

The introduction of a carbon tax generates the largest emission reductions (10–14%) and sharply reduces fossil energy demand (12–18%), but at the cost of a decline in real GDP (–0.4% to –0.8%). In contrast, the combined scenario integrating energy efficiency improvements with carbon pricing delivers more balanced outcomes, with CO_2 emissions falling by 12–16%, energy intensity declining by 6–9%, and GDP effects limited to between –0.1% and +0.2%. Overall, the results suggest that while energy efficiency–based green infrastructure investment yields simultaneous economic and environmental benefits, combining it with carbon pricing provides a more effective and economically sustainable pathway for Morocco's energy transition.

Key-Words: Public infrastructure, Climate, Energy and the Macroeconomy, CGE, Carbon tax, Morocco.

Jel-classification : H54, Q43, Q54, C68, O47.