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Assessing the Impact of Carbon Taxation on Productivity Indicators Using a System Dynamics Approach: Evidence from Iran

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ABSTRACT

This study aims to evaluate how carbon taxation influences productivity indicators in Iran by modeling the dynamic interactions among carbon emissions, green tax revenues, economic welfare, and productivity over time. The research employs a quantitative simulation framework based on system dynamics modeling. Annual macroeconomic time-series data for Iran covering the period 1992–2020 were used, including gross domestic product, carbon emissions, green tax proxies, government budget components, inflation, investment, population, productivity, and interest rates. The model was implemented in Vensim and constructed around endogenous feedback loops linking environmental taxation, fiscal capacity, welfare, and productivity. Six policy scenarios were simulated, capturing alternative trajectories of GDP growth, carbon emission changes, and green tax adjustments, including both historical and forecast horizons. Model validation procedures included structural verification, sensitivity analysis, and consistency testing. Simulation results indicate that productivity responds primarily through a welfare-mediated channel. A sustained 3% increase in GDP generated rising green tax revenues, higher economic welfare, and long-term productivity growth. In contrast, an 11% increase in carbon emissions reduced welfare and productivity despite marginal tax revenue gains. A 2.5% increase in green taxation improved both welfare and productivity by reducing pollution and strengthening human capital conditions. Forecast scenarios confirmed that growth combined with green taxation promotes productivity, while emissions growth alone exerts limited positive economic influence. The productivity trajectory is therefore highly sensitive to fiscal–environmental policy design. Carbon taxation, when integrated into a coherent fiscal framework, functions as both an environmental policy tool and a driver of productivity growth by strengthening economic welfare and supporting sustainable development pathways.

Keywords: Carbon Tax; Green Tax; Productivity; Economic Welfare; System Dynamics; Environmental Policy; Iran

Introduction

The accelerating pace of climate change and environmental degradation has fundamentally reshaped the policy priorities of modern economies, compelling governments to reconsider the structure of fiscal systems and their role in steering production and consumption toward sustainability. Carbon emissions, primarily driven by fossil fuel–based growth models, now represent not only an ecological threat but also a structural economic risk that

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undermines long-term productivity, public health, and social welfare. In response, environmental taxation—particularly carbon taxation—has emerged as one of the most influential instruments for internalizing environmental externalities while simultaneously generating fiscal resources for green transformation (1-4). Unlike command-and-control regulations, carbon taxes leverage market mechanisms to realign private incentives with social costs, encouraging firms and households to shift toward cleaner technologies and more efficient resource use.

The growing body of international evidence demonstrates that well-designed carbon tax systems can effectively reduce emissions while preserving macroeconomic stability and promoting sustainable development (5-8). However, the economic consequences of carbon taxation extend beyond emissions control. By influencing energy prices, production costs, investment patterns, and public revenues, carbon taxation reshapes the entire macroeconomic environment in which productivity evolves. Productivity—the efficiency with which labor, capital, and technology generate output—lies at the heart of long-term economic prosperity. Understanding how environmental taxation affects productivity dynamics is therefore essential for designing climate policies that foster not only ecological sustainability but also durable economic growth (9, 10).

Recent research highlights the complex channels through which carbon taxes affect productivity. On the firm side, environmental taxes encourage technological upgrading, cleaner production processes, and resource efficiency, which can enhance total factor productivity in the long run (11-13). At the same time, transitional costs—including higher energy prices and adjustment burdens—may exert short-term pressures on output and competitiveness, particularly in energy-intensive sectors (14-16). On the public finance side, carbon tax revenues provide governments with stable fiscal space to invest in human capital, clean infrastructure, and innovation, thereby reinforcing productivity growth through indirect welfare-enhancing mechanisms (9, 17, 18). These intertwined effects create dynamic feedback structures that cannot be captured adequately by static or partial-equilibrium models.

The literature increasingly recognizes that the success of carbon taxation depends not only on its environmental effectiveness but also on its integration within broader institutional and fiscal frameworks. Governance quality, legal environment, and tax system design critically shape how environmental taxes translate into economic outcomes (9, 10, 19). In emerging and developing economies, where energy intensity remains high and structural transformation is ongoing, carbon taxation presents both an opportunity and a challenge. While it can accelerate the transition toward cleaner growth, its macroeconomic consequences require careful management to avoid undermining investment, employment, and social stability (8, 20).

Iran represents a particularly relevant context for studying these dynamics. The Iranian economy is characterized by high energy intensity, substantial fossil fuel dependence, persistent environmental pressures, and the urgent need for productivity enhancement to sustain growth under fiscal constraints. Environmental taxes, including carbon-oriented levies, have gradually entered policy discourse as tools for reconciling economic development with environmental protection (1, 2, 21). Yet, empirical evidence on how such taxes affect productivity and welfare in Iran remains limited, fragmented, and often based on static analytical frameworks that fail to capture the dynamic interdependencies of the macroeconomy.

International studies provide valuable insights but reveal considerable heterogeneity in outcomes across countries and sectors. For example, carbon tax policies in European economies have demonstrated the potential to strengthen fiscal resilience and stimulate structural adjustment during crises (4). In China, the coordination between renewable portfolio standards and carbon taxation has proven crucial for aligning energy markets with emission reduction goals (5). Empirical evidence from Bangladesh and Belt and Road economies indicates that green taxation interacts strongly with governance quality and financial development in shaping sustainability and productivity outcomes (7, 9). These findings underscore the necessity of country-specific analysis grounded in realistic macroeconomic structures.

Traditional econometric approaches, while valuable, often struggle to capture the nonlinear feedback loops, delayed effects, and policy-induced structural changes inherent in environmental taxation systems. As a result, recent research increasingly turns toward system-oriented modeling techniques capable of representing endogenous dynamics and long-term trajectories. System dynamics modeling, in particular, offers a powerful framework for integrating economic, environmental, and fiscal subsystems within a unified analytical structure. By explicitly representing stocks, flows, feedback loops, and time delays, system dynamics allows researchers to explore how carbon taxation propagates through welfare, investment, productivity, and emissions over extended horizons (6, 17, 22).

The integration of welfare into productivity analysis is especially important. Welfare influences labor motivation, health outcomes, education attainment, and social stability—all of which constitute foundational inputs to productivity growth. Environmental degradation directly erodes welfare through adverse health effects, environmental risks, and rising social costs, while environmental taxation, when properly designed, can reverse these trends by improving environmental quality and financing social investment (12, 18, 20). Consequently, the productivity impact of carbon taxation cannot be understood solely through firm-level cost structures; it must be evaluated through its broader macroeconomic and social consequences.

Moreover, carbon taxation interacts with supply chains, market structures, and international competitiveness. Optimization studies show that carbon taxes influence coordination mechanisms in closed-loop and global supply chains, affecting both emissions and production efficiency (15, 16, 23). Fiscal policies also shape export sophistication and green finance development, reinforcing the strategic role of environmental taxation in modern economic systems (9, 13). These interdependencies highlight the necessity of modeling carbon taxation as part of an integrated economic system rather than as an isolated policy instrument.

In the Iranian context, early theoretical and policy-oriented research emphasized the legal and environmental justification for green taxation, arguing that such instruments can safeguard environmental rights while supporting economic rationality (1, 2). More recent work has advanced optimization models for determining appropriate carbon tax levels in the power generation sector using life-cycle approaches (21). Yet, a comprehensive macro-dynamic assessment of how carbon taxation affects productivity through welfare and fiscal channels remains largely unexplored.

This gap becomes increasingly consequential as Iran faces mounting environmental pressures, fiscal constraints, and the urgent necessity to enhance productivity. Policymakers require evidence-based guidance on whether carbon taxation can serve as a dual instrument for environmental protection and productivity growth, and under what structural conditions such outcomes are feasible. Without such understanding, environmental fiscal reforms risk being perceived as purely restrictive measures rather than as catalysts for sustainable economic transformation.

The present study addresses this critical gap by developing a system dynamics model of the Iranian economy that explicitly integrates carbon taxation, economic welfare, and productivity within a unified feedback framework. By simulating alternative policy scenarios using long-term macroeconomic data, the study provides a dynamic evaluation of how carbon tax policies propagate through fiscal channels, welfare adjustments, and productivity outcomes. This approach advances the existing literature by moving beyond static estimations and capturing the endogenous, time-dependent interactions that govern real-world policy impacts (6, 8, 17, 22).

The aim of this study is to examine the impact of carbon taxation on productivity indicators in Iran using a system dynamics modeling approach that captures the dynamic interactions among carbon emissions, green tax revenues, economic welfare, and productivity over time.

Methods and Materials

This study is designed as a quantitative, simulation-based policy evaluation using **system dynamics** to capture the feedback-rich, time-dependent interactions between carbon taxation, emissions, public spending, human capital formation, production decisions, and economy-wide productivity outcomes. Because the research question concerns macro-structural mechanisms rather than individual attitudes or behaviors, the "participants" are **the modeled economic agents and sectors** embedded in the dynamic system, namely a representative household sector, a representative firm/production sector, and the government/public sector, linked through goods, factor, and fiscal accounts. The model is implemented in discrete time $t = 0,1,2, \dots, T$ and is constructed to reproduce a baseline trajectory for output, emissions, and productivity prior to policy intervention, and then to generate counterfactual trajectories under alternative carbon-tax regimes. The policy shock is introduced as a carbon (pollution) tax rate applied to emission-generating output (or directly to emissions proportional to output), and the resulting tax revenues are endogenously recycled into government spending categories that affect pollution abatement and human-capital productivity, consistent with a green-growth policy logic.

Model parameterization and calibration rely on secondary macroeconomic and environmental statistics consistent with national accounts and emissions accounting. The data inputs required are time series (annual or quarterly, depending on availability) for aggregate output Y_t, consumption C_t, physical capital K_t, labor/human-capital proxies, wage and capital return proxies (w_t, r_t), government expenditures (with separable identification of education-related spending E_t and pollution-prevention/abatement spending D_t), total fiscal revenues, and an emissions proxy consistent with the modeling assumption that one unit of output generates one unit of pollution. Where direct emissions inventories are available, emissions Em_t are used; otherwise, emissions are proxied by energy-related CO_2 and mapped into the model's pollution flow P_t via scaling. The key structural "tools" are the governing equations that define household optimization, production, pollution generation and reduction, and the public budget and recycling rule. The representative household's discounted lifetime welfare is modeled as

$$W_0 = \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \Phi_p \log P_t\right),$$

where $0 < \beta < 1$ is the discount factor, C_t is consumption, P_t is effective pollution, and Φ_p reflects the social disutility weight of pollution. The household budget constraint evolves as

$$K_t = [1 - \delta_K + (1 - \tau_t^K) r_t] K_{t-1} + (1 - \tau_t^H) w_t\, u_t\, H_{t-1} - C_t + T_t,$$

where δ_K is capital depreciation, τ_t^K is the capital-income tax rate, τ_t^H is the labor-income tax rate, $u_t H_{t-1}$ is effective labor input, and T_t are lump-sum transfers. Human capital accumulates endogenously with time allocation to education and is negatively affected by pollution:

$$H_t = [1 + \beta_t(1 - u_t) - \eta_t P_t]H_{t-1},$$

with $\eta_t > 0$capturing the adverse effect of pollution on learning/health, and $\beta_t$representing productivity of human-capital formation. Public support to education raises $\beta_t$via

$$\beta_t = b\left(\frac{E_t}{Y_t}\right)^{\xi},$$

where $b > 0$and $0 \leq \xi \leq 1$represent the level and elasticity of educational productivity with respect to the education-spending share.

The representative firm side is modeled with a Cobb–Douglas technology with effective labor:

$$Y_t = A\, K_{t-1}^{\alpha}(u_t H_{t-1})^{1-\alpha}, 0 < \alpha < 1,$$

and a policy-relevant carbon-tax wedge is applied to emission-generating output (equivalently emissions proportional to output). Profit is given by

$$\pi_t = (1 - \tau^p)Y_t - r_t K_{t-1} - w_t u_t H_{t-1},$$

where $\tau^p$is the carbon/pollution tax rate. Factor prices follow marginal-product conditions net of the carbon-tax wedge:

$$r_t = (1 - \tau^p)\frac{\alpha Y_t}{K_{t-1}}, w_t = (1 - \tau^p)\frac{(1 - \alpha)Y_t}{u_t H_{t-1}}.$$

Pollution is treated as a flow that can be reduced through government abatement spending. Consistent with the guide's functional form, effective pollution is modeled as decreasing in the abatement share:

$$P_t = \left(\frac{D_t}{Y_t}\right)^{-\mu}, \mu > 0,$$

so higher $D_t$relative to $Y_t$lowers pollution. Government revenue aggregates taxes on capital income, labor income, and pollution/output:

$$\bar{A}_t = \tau_t^K r_t K_{t-1} + \tau_t^H w_t u_t H_{t-1} + \tau_t^p Y_t,$$

and revenues are recycled into education spending E_t, abatement spending D_t, and transfers $T_t$using fixed shares:

$$E_t = \theta_1 \bar{A}_t, D_t = \theta_2 \bar{A}_t, T_t = \theta_3 \bar{A}_t, \theta_1 + \theta_2 + \theta_3 = 1, \theta_i \in [0,1].$$

The goods-market identity closes the macro system:

$$Y_t = C_t + [K_t - (1 - \delta_K)K_{t-1}] + Z_t,$$

where $Z_t$denotes total public outlays (equal to total revenues in the balanced-budget closure).

To operationalize the article's focus on productivity indicators, the model computes multiple productivity series endogenously from simulated states. A core indicator is a system-consistent proxy for total factor productivity (TFP) inferred from the production function:

$$TFP_t = \frac{Y_t}{K_{t-1}^{\alpha}(u_t H_{t-1})^{1-\alpha}}.$$

Complementary indicators include labor productivity

$$LP_t = \frac{Y_t}{u_t H_{t-1}},$$

and, where an emissions or energy proxy is used, carbon productivity (economic output per unit of emissions)

$$CP_t = \frac{Y_t}{Em_t},$$

with Em_tmeasured directly or proxied consistently with the model's pollution-flow assumption. In system dynamics implementation, the above relationships are encoded as stock–flow equations, where stocks include $K_t$and H_t, flows include investment (implied by $K_t - (1 - \delta_K)K_{t-1}$) and net human-capital accumulation, and auxiliaries include Y_t, P_t, taxes, and spending allocations.

Analysis proceeds through structured system-dynamics model development, calibration, validation, and policy experimentation. First, a causal-loop structure is formalized to reflect reinforcing and balancing feedbacks central to carbon taxation and productivity, including: the balancing loop where higher carbon tax reduces after-tax production incentives and thus output/emissions; the reinforcing loop where carbon-tax revenue increases public investment in education and abatement, which improves human capital and reduces pollution; and the long-run feedback where lower pollution mitigates productivity losses (via the human-capital equation) and supports higher effective labor and output. Second, the stock–flow model is implemented and calibrated to baseline macro trajectories by selecting parameter values $(\alpha, \delta_K, \beta, \Phi_p, \eta, \mu, \theta_1, \theta_2, \theta_3)$that replicate pre-policy movements in output, fiscal aggregates, and emissions/pollution proxies within acceptable error bands. Third, model credibility is assessed using standard system-dynamics validation routines: dimensional consistency checks, extreme-condition tests (e.g., $\tau^p \rightarrow 0$and high τ^pregimes), historical fit tests for key observables, and sensitivity analysis to confirm that qualitative policy conclusions are robust to plausible parameter ranges.

Policy evaluation is conducted via scenario simulation over a medium-to-long horizon. The baseline scenario maintains the observed/assumed carbon-tax path, while counterfactual scenarios vary the carbon tax rate $\tau^p$and the revenue recycling shares $\theta_1, \theta_2, \theta_3$to isolate how alternative fiscal designs shift productivity outcomes. For each scenario, the model produces trajectories for TFP_t, LP_t, CP_t, Y_t, P_t, and welfare-consistent measures derived from the utility function, enabling comparison of short-run adjustment costs versus long-run productivity gains. Finally, uncertainty is handled through multi-parameter sensitivity runs (and, where feasible, Monte Carlo sampling), reporting the distribution of productivity impacts under parameter uncertainty, with particular attention to the strength of pollution's adverse effect on human capital $(\eta_t)$and the efficacy of abatement spending (μ), as these channels determine whether carbon taxation generates a net productivity dividend in the long run.

Findings and Results

The dynamic model of carbon taxation and productivity was estimated using Iranian time-series macroeconomic data for the period **1992–2020**. The simulation structure was implemented in the Vensim environment based on the system equations governing labor demand, liquidity, economic welfare, productivity, government budget, and gross fixed capital formation. The conceptual core of the model assumes that changes in GDP and carbon emissions do not influence productivity directly, but rather operate through the intermediate channels of green taxation and economic welfare, with welfare serving as the primary transmission mechanism into productivity. This structure allows the model to capture the dynamic, non-linear interactions between environmental policy, macroeconomic performance, and productivity outcomes.

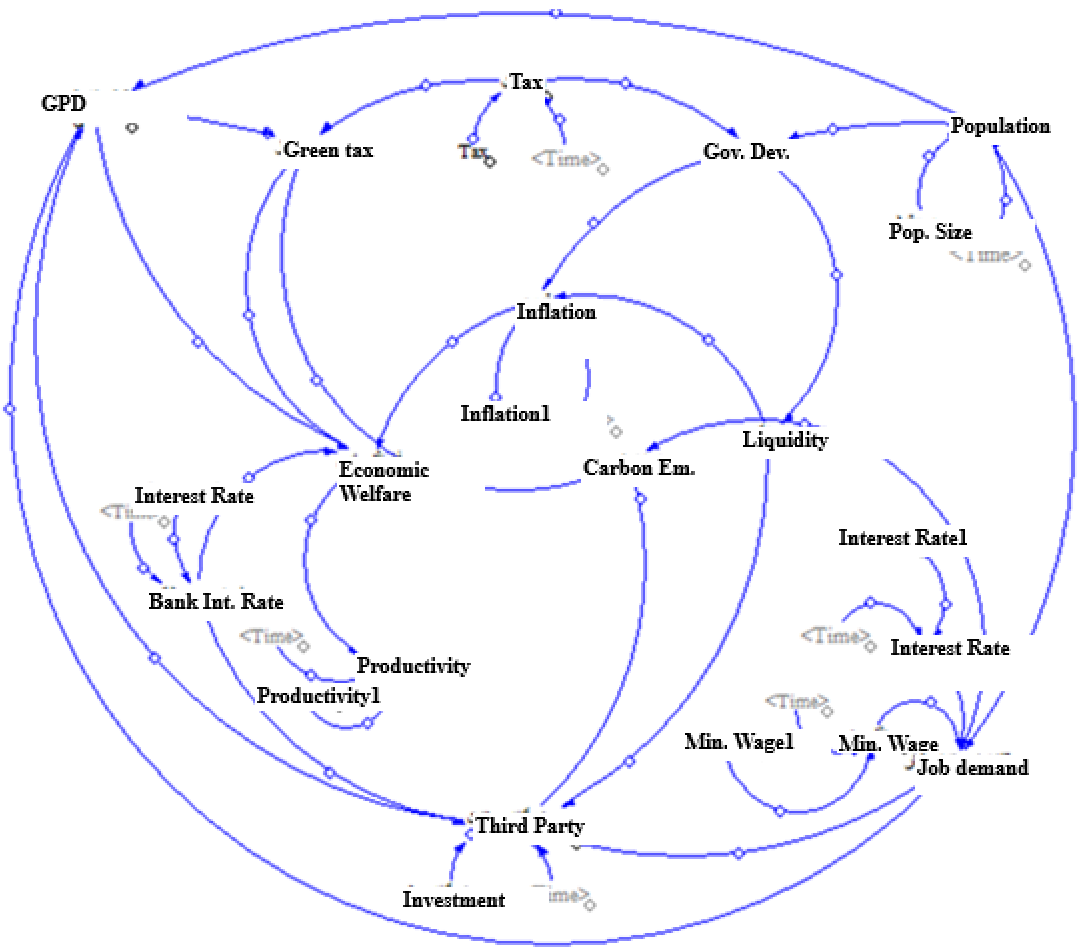

Figure 1. Dynamic system of carbon taxation, economic welfare, and productivity

Figure 1 illustrates the causal architecture of the model, highlighting GDP and carbon emissions as the principal exogenous drivers. These variables affect the green tax stream, which in turn reshapes economic welfare. Economic welfare functions as the decisive state variable that determines productivity over time, thereby structuring the entire policy transmission mechanism of the system.

Scenario 1: 3 percent increase in GDP (1992–2020).

This scenario evaluates the effect of a sustained 3 percent increase in GDP, reflecting the historical average growth rate of the Iranian economy. The simulation shows that higher GDP systematically expands the green tax base, primarily through increased production and associated carbon emissions. The enlarged green tax flow improves economic welfare by strengthening public fiscal capacity and by encouraging reductions in environmentally harmful activity. Rising welfare subsequently elevates productivity through improved labor motivation, health, and human capital efficiency. Over the entire simulation horizon, productivity, welfare, and green tax all follow an upward trajectory, confirming that economic growth, when filtered through a green taxation mechanism, can generate reinforcing gains in welfare and productivity.

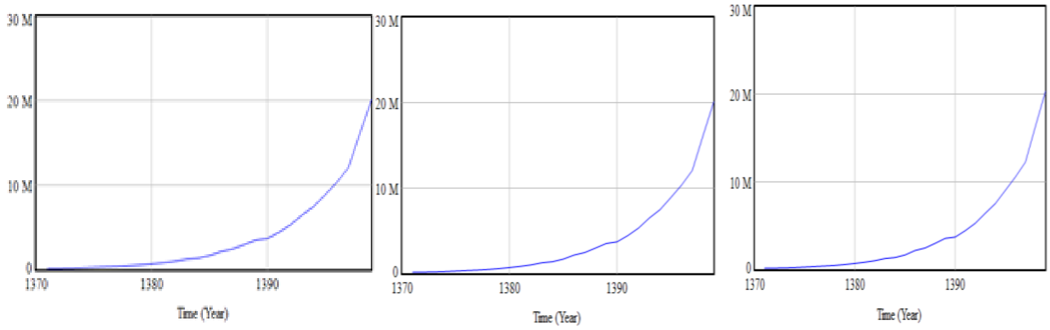

Figure 2. Productivity response to a 3 percent increase in GDP (Left to right: Productivity, Economic Welfare, Green Tax)

Scenario 2: 11 percent increase in greenhouse gas emissions (1992–2020).

This scenario isolates the effect of emissions growth by imposing an 11 percent increase in carbon emissions, consistent with historical trends. The model reveals that rising emissions, when transmitted through the green tax channel, lead to a deterioration of economic welfare and a consequent decline in productivity. Increased pollution intensifies environmental and health burdens, eroding welfare and undermining workforce effectiveness. The negative welfare shock outweighs any fiscal gains from the expanded tax base, producing a net reduction in productivity. The results confirm the centrality of environmental quality in sustaining welfare and productivity within the modeled economy.

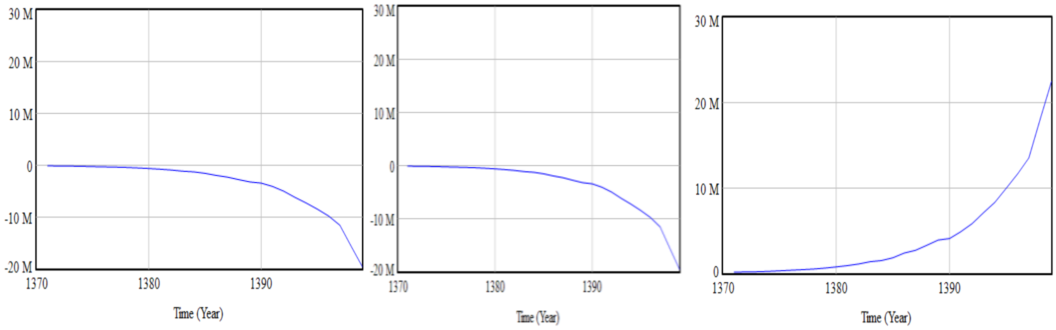

Figure 3. Effects of an 11 percent increase in emissions on green tax, welfare, and productivity (Left to right: Economic Welfare, Productivity, Green Tax)

Scenario 3: 2.5 percent increase in green tax (1992–2020).

This scenario assesses the impact of a 2.5 percent rise in green taxation, reflecting the long-term average of environmental tax adjustments. The simulation demonstrates that higher green taxation reduces fossil fuel consumption and pollution intensity, thereby improving economic welfare. Enhanced welfare strengthens labor motivation, health outcomes, and human capital productivity, producing a sustained increase in overall productivity. The scenario provides strong evidence that environmentally oriented fiscal reform can deliver both ecological and economic dividends when welfare operates as the primary adjustment channel.

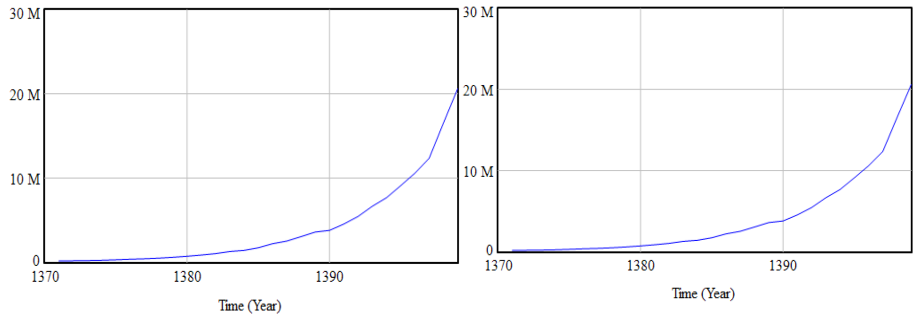

Figure 4. Effects of a 2.5 percent increase in green tax on welfare and productivity (Left to right: Economic Welfare and Productivity)

Scenario 4: Forecasted 3 percent GDP growth (2021–2027).

In the forward-looking simulation period, sustained GDP growth initially increases carbon emissions due to the energy-intensive structure of the economy. However, the associated expansion of the green tax base strengthens public revenues and supports welfare-enhancing investments in health, education, and environmental protection. Despite higher emissions, the combined effect of growth and green fiscal recycling produces steady improvements in welfare and productivity. This scenario demonstrates that economic expansion, when guided by green taxation, can remain compatible with long-term productivity growth.

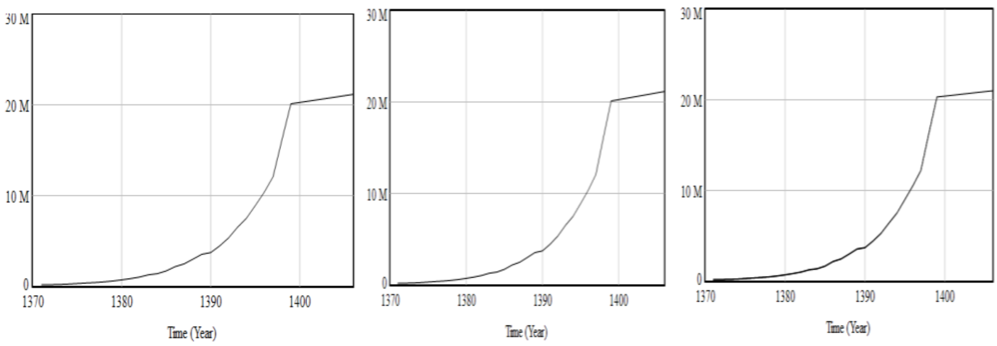

Figure 5. Forecasted effects of 3 percent GDP growth on green tax, welfare, and productivity (Left to right: Productivity, Economic Welfare, Green Tax)

Scenario 5: Forecasted 11 percent emissions growth (2021–2027).

This scenario explores the future impact of rising emissions while holding GDP growth constant. The simulation indicates that emissions growth alone produces only marginal changes in the green tax base and therefore has limited influence on welfare and productivity. The dominance of GDP over emissions in shaping fiscal capacity becomes evident: without parallel economic expansion, rising pollution cannot generate sufficient fiscal resources to offset its welfare costs. The scenario underscores the necessity of integrating environmental policy with broader economic reform.

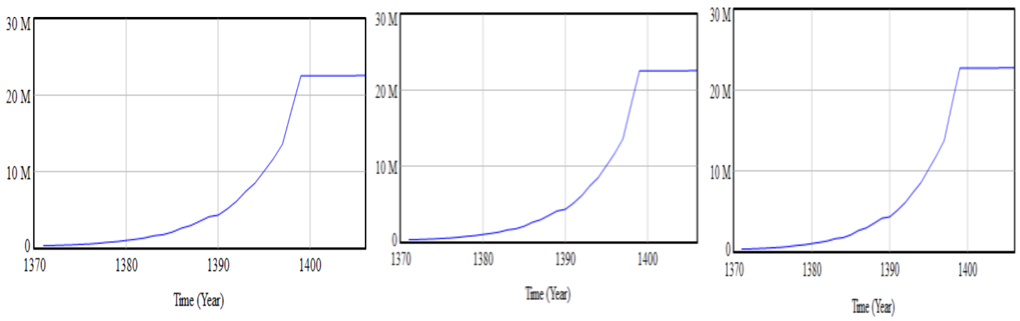

Figure 6. Forecasted effects of emissions growth on green tax, welfare, and productivity (Left to right: Productivity, Economic Welfare, Green Tax)

Scenario 6: Forecasted 2.5 percent increase in green tax (2021–2027).

The final scenario projects the effects of a gradual 2.5 percent increase in green taxation over six years. The results show a steady improvement in economic welfare driven by cleaner production patterns, reduced pollution exposure, and enhanced public health conditions. These welfare gains translate into higher productivity through improved labor performance and reduced environmental drag on economic efficiency. The simulation confirms that moderate, sustained green tax reform can strengthen productivity while supporting environmental sustainability.

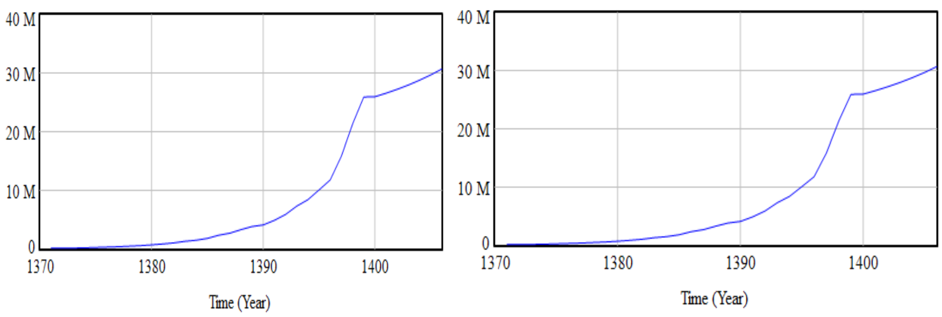

Figure 7. Forecasted effects of a 2.5 percent increase in green tax on welfare and productivity (Left to right: Productivity and Economic Welfare)

Discussion and Conclusion

The findings of this study provide strong empirical and dynamic-system evidence that carbon taxation, when embedded within a coherent fiscal–environmental framework, can function not only as an environmental corrective mechanism but also as a catalyst for sustained productivity growth through its welfare-mediated effects. The simulation results demonstrate that changes in productivity are not driven by carbon taxation in isolation; rather, productivity responds to a chain of interactions whereby GDP and carbon emissions shape green tax flows, green tax revenues influence economic welfare, and welfare in turn determines productivity performance. This welfare-centered transmission mechanism confirms the theoretical proposition that environmental policy must be evaluated as part of a broader macroeconomic ecosystem rather than as a narrow regulatory intervention. Similar conclusions have been advanced in international studies emphasizing that the macroeconomic success of carbon taxation depends on its integration with public finance, investment behavior, and institutional capacity (1, 2, 8, 10).

The first scenario, involving a sustained 3 percent increase in GDP, revealed that higher output expands the green tax base and strengthens public fiscal capacity, thereby enhancing economic welfare and productivity simultaneously. This outcome aligns with the literature demonstrating that carbon taxes, when associated with growth-driven fiscal expansion, can generate long-term productivity dividends by financing technological upgrading, education, and clean infrastructure (6, 9, 13). The results also reinforce the view that productivity gains materialize not merely from output growth but from the manner in which growth is taxed and redistributed within the economy. Similar growth–tax–productivity interactions have been reported in analyses of low-carbon fiscal reform in China and European economies (4, 5). By explicitly modeling the feedback loops between fiscal revenues, welfare, and productivity, this study extends those findings and demonstrates that welfare improvement constitutes the central structural bridge linking carbon taxation to productivity enhancement.

The second scenario, which examined an 11 percent increase in carbon emissions, generated a contrasting dynamic: emissions growth eroded economic welfare and reduced productivity despite marginal increases in green tax revenues. This result underscores the dominant role of environmental quality in shaping welfare and, through welfare, productivity. The deterioration of welfare observed in the model reflects well-documented channels through which pollution damages public health, labor efficiency, and human capital accumulation (12, 18). Empirical research consistently confirms that environmental degradation imposes significant economic costs that ultimately suppress productivity and growth (15, 16). The present study complements this literature by showing that unless carbon taxation is sufficiently strong and well-targeted to offset the welfare losses associated with pollution, emissions growth will dominate fiscal gains and generate net productivity decline.

The third scenario, involving a 2.5 percent increase in green taxation, revealed that environmental tax reform can improve both welfare and productivity even in the absence of rapid GDP growth. This outcome directly supports the growing body of evidence indicating that green taxes promote cleaner production, reduce environmental externalities, and stimulate productivity-enhancing innovation (7, 11, 17). The positive response of productivity to higher green taxation also reflects the role of environmental fiscal policy in strengthening corporate responsibility and environmental governance, which in turn improve firm-level efficiency and long-term competitiveness (12, 13). From a macroeconomic perspective, the scenario confirms that green taxation can serve as a structural instrument for aligning environmental sustainability with economic performance.

The forward-looking simulations further reinforce these conclusions. Under the projected GDP growth scenario, the model demonstrated that although economic expansion initially increases carbon emissions, the associated increase in green tax revenues enables welfare-enhancing investments that ultimately support rising productivity. This pattern reflects the policy logic emphasized in recent research on sustainable growth strategies in developing economies, where environmental taxation plays a crucial role in financing the transition toward clean technologies and resilient economic structures (8, 9). The model therefore illustrates how growth and environmental taxation can be mutually reinforcing when policy design internalizes environmental costs while preserving fiscal capacity.

By contrast, the forecast scenario focusing on emissions growth alone revealed that emissions expansion without corresponding GDP growth exerts only weak influence on green tax flows and thus fails to generate meaningful welfare or productivity improvements. This result echoes findings in environmental economics that emphasize the limited effectiveness of isolated environmental interventions in the absence of complementary macroeconomic reforms (10, 19). The Iranian context, characterized by high energy intensity and structural dependence on fossil fuels, further amplifies this dynamic: without broad-based economic transformation, environmental policy lacks the fiscal leverage necessary to produce sustained productivity gains.

The final scenario, projecting a gradual 2.5 percent increase in green taxation over six years, demonstrated that moderate but consistent environmental tax reform generates cumulative welfare improvements and rising productivity. This finding is consistent with empirical studies showing that stable environmental tax regimes encourage long-term investment in clean technologies and human capital, thereby improving productivity and export sophistication (9, 13, 17). It also resonates with evidence from European carbon tax reforms, where fiscal-environmental policy has supported both ecological objectives and economic resilience (4).

Taken together, the results highlight three fundamental insights. First, productivity outcomes of carbon taxation are primarily mediated by economic welfare rather than by direct cost or price effects alone. Second, environmental quality exerts a powerful influence on productivity through health, human capital, and labor motivation channels, confirming the macroeconomic importance of ecological conditions. Third, the success of carbon taxation depends on its integration with growth strategies, fiscal recycling mechanisms, and institutional quality. These conclusions reinforce the growing consensus that environmental fiscal policy must be embedded within comprehensive development frameworks to achieve sustainable productivity growth (1, 2, 8, 10).

This study relies on simulation-based modeling and secondary macroeconomic data, which necessarily abstracts from micro-level behavioral heterogeneity and firm-specific adjustment mechanisms. Parameter calibration was constrained by data availability, and although extensive sensitivity analysis was conducted, some structural uncertainties remain regarding long-term technological change and energy transition pathways. Moreover, the model does not explicitly incorporate international trade shocks or geopolitical influences that may affect Iran's environmental and fiscal dynamics.

Future studies could integrate firm-level and household-level microdata into the dynamic framework to capture heterogeneous responses to carbon taxation. Expanding the model to include international trade, capital flows, and energy price volatility would further improve policy realism. Comparative cross-country applications of the framework could also enhance generalizability and inform regional climate–fiscal coordination strategies.

Policymakers should design carbon tax reforms as part of an integrated fiscal–development strategy that prioritizes welfare enhancement and productivity growth alongside emissions reduction. Revenues from environmental taxation should be transparently recycled into education, health, clean infrastructure, and innovation systems to maximize long-term productivity returns. Stable and predictable environmental tax regimes will strengthen investor confidence and accelerate the transition toward a resilient low-carbon economy.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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