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Meta-Analysis of Competitiveness and Innovation and Carbon Taxation Strategic Adaptation: An Implication for Developing Economies

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Abstract

The purpose of this study was to systematically review and conduct a meta-analysis on the relationship between competitiveness and innovation, and carbon taxation strategic adaptation. The competitiveness and innovation, particularly employment, total productivity, and foreign direct investment capability of a nation, could predict the adoption of carbon taxation strategies, especially in developing economies where the need for economic growth and development may override the need to address the existential threat of climate change. Carbon taxation, environmental tax, green tax, and carbon emissions trading have been shown to catalyze the reduction of carbon dioxide emissions, which is a key ingredient of climate change. Using data drawn from Scopus and Web of Science databases, a total of 16 articles were reviewed and included in meta-analysis following the guidance of the PRISMA flowchart. The findings of the study revealed that random-effects results indicated pooled effect $\mu = -0.014$ (SE = 0.005; 95% CI -0.024, -0.005; k = 16); heterogeneity $Q(15) = 50.15$, $p = 1.1\times10^{-5}$; $I^2 = 70.1\%$; $\tau^2 = 0.000204$; 95% PI -0.044 to 0.015; region differences not significant (Q-between(2) = 0.15, $p = 0.926$). The findings reveal a small negative average with substantial heterogeneity and a PI crossing zero, which implies that outcomes are design-sensitive to exposure, safeguards, credibility of ramps, and innovation finance. It was concluded that transitional pressures exist but are not universal because with credible, innovation-oriented design, net competitiveness and innovation effects often cluster near neutral. The study recommends that governments legislate inflation-indexed ramps, maximize coverage with temporary, targeted EITE safeguards, recycle revenues to productivity and innovation, particularly on R&D, clean capex, and skills. It should equally reduce non-price frictions that are permitting, and infrastructure to enable firms to respond by investing rather than retrenching to cut costs.

Keywords: *Meta-Analysis, Competitiveness, Innovation, Carbon Taxation, Strategic Adaptation, Developing Economies*

1.0 Introduction

Globally, it is an important part of the diversification of economic instruments that countries have to address climate change and its impact on environmental degradation (Metcalf, 2019; 2021). Carbon taxation may provide the dual benefit of expanding revenues that the government needs for public investments towards transitioning to green development (Metcalf & Stock, 2020). Carbon taxes can also be instrumental in creating incentives that reduce emissions and pollution, effectively contributing to the mitigation of climate change effects (Dussaux, 2020). According to data from the World Bank (2022a) as of May 2022, only 46 jurisdictions had introduced carbon pricing schemes. These schemes covered a total of 23% of greenhouse gas (GHG) emissions globally. Among the 46 jurisdictions, 36 jurisdictions priced carbon through a carbon tax, covering about 5.7% of the worldwide GHG emissions. These jurisdictions that have implemented carbon tax charge carbon tax rates ranging from US$0.8 per ton of carbon dioxide (CO2) equivalent (CO2e) in Poland, to the highest in Uruguay at US$137 per ton of CO2e. Norway has the highest proportion of its carbon tax to national GHG emissions at 98%, Spain at 2.9% and South Africa at 0.9%. In Africa, only South Africa has implemented a carbon tax since 2019; the proportion of its carbon tax revenue to the national GHG is below even the least in the developed countries. The adoption of a carbon tax in Africa has been particularly slow due to the high tax rates set, the informality of economies, limited tax brackets, and few formal sectors (Yiadom et al., 2024). Further, the introduction of carbon taxes into already established taxes has complex implications, considering that existing taxes are already a burden to most taxpayers (Bashir et al., 2021).

1.1 Problem Statement

The disruptive nature of climate change effects requires strategic adaptation to carbon taxation as an important contribution to emissions reductions. However, barriers such as high tax rates, informal economies, limited tax brackets, and political resistance have hindered carbon taxation strategic adaptation in developing economies (World Bank, 2022a). Therefore, formulating laws, policies, and regulations is important to facilitate carbon taxation strategic adaptation and emission reduction in both developed and developing economies. Though a critical avenue to reducing carbon emissions, strategic adaptation to carbon taxation policies must be grounded on existing empirical evidence of what works, how it works, and its likely impact on society and the economy (Metcalf & Stock, 2020; Koppl & Schratzenstaller, 2022).

The existing evidence points to carbon taxation's effectiveness in mitigating the socio-economic impact of climate change and its effect on competitiveness, innovation, macroeconomic performance, environmental effectiveness, and distributional implications (Koppl & Schratzenstaller, 2022). Carbon tax effectiveness in the United Kingdom, for instance, found that the Climate Change Levy (a form of the carbon tax but differentiated across fuels) facilitated the decrease in carbon dioxide emissions by 8.4%, energy intensity by 18.1%, and electricity use by 22.6% between 1999 and 2004 (Martin et al., 2014). In France, a carbon tax reduced CO2 emission by 1%-5% between 2014 and 2018 (Dussaux, 2020). Still, in Switzerland, between 2008 and 2015, carbon emissions were reduced from an estimated 6.9 million tons by carbon taxation policies (Metcalf & Stock, 2021). In British Columbia (Canada), several studies investigated the model of carbon tax using variables related to the environment. A total reduction of between 5%-15% was realized between 2008 and 2015 (Murray & Rivers, 2015). However, Pretis (2022), using various econometric models, found that CO2 emissions decreased by 5% in the transport sector, though the aggregate reduction could not be detected between 2008 and 2016; the reason being that carbon was low-priced to create any significant impact.

Drawn from the evidence of Martin et al. (2014), Dussaux (2020), and Metcalf and Stock (2021), different countries are at different stages of carbon taxation adaptation, with a possible influence of sustainability initiatives implemented to promote the uptake of carbon taxation policies. Evidence shows that the inclusion of sustainability initiatives such as green investments and technology innovation has increased the acceptance of carbon taxation (Qiao et al., 2024). Sweden, for instance, gradually increased their carbon tax and used the revenue to support clean energy and public transport initiatives, consequently leading to carbon taxation strategies being politically and socially acceptable (Jonsson, 2023). Though evidence has proven that carbon taxation strategic adaptation is critical to the reduction of carbon emissions, there is a lack of unified understanding of the modalities for its implementation, specifically among developing economies. It is against the backdrop of this gap that this study sets out to examine, through a systematic review and meta-analysis, the extent to which carbon taxation is implicated by competitiveness and innovation.

1.2 Objectives of the Study

To establish the effect of competitiveness and innovation on carbon taxation strategic adaptation implications for developing economies.

1.3 Research Question

What is the influence of competitiveness and innovation on carbon taxation strategic adaptation for developing economies?

2.0 Literature Review

This section examines the theoretical foundations and empirical evidence surrounding the relationship between competitiveness, innovation, and carbon taxation strategic adaptation. The literature review is structured to first establish the theoretical frameworks that underpin this research, followed by an analysis of existing empirical studies that have investigated these relationships in various contexts.

2.1 Theoretical Framework

The theoretical foundation for understanding the relationship between competitiveness, innovation, and carbon taxation strategic adaptation draws upon two complementary frameworks that address the complex interactions between economic, social, and environmental dimensions of sustainable development.

2.1.1 Sustainable Development Theory

The theory posits that economic, social, and environmental systems are interconnected and mutually dependent (Mitcham, 1995; Zhang, 2018). Any development strategy must take into account the interactions and trade-offs between these dimensions (Sadegh, 2014). The emphasis is on the importance of meeting the needs of the present without compromising the ability of future generations to meet their own needs using the same resources (Pagett, 2018; Silvestre & Tirca, 2019). Sustainable development theory helps identify and navigate trade-offs between economic growth, social equity, and environmental sustainability (Hansmann et al., 2012). It can inform decision-making processes related to carbon taxation strategic adaptation, particularly when an economy considers being innovative and competitive (Mensah, 2019).

Carbon taxation policies can contribute to resilience by incentivizing investments in low-carbon technologies, which enhance energy efficiency while diversifying economies to continuously remain competitive and innovative despite the implementation of carbon taxation policies. Hassan et al. (2022) anchored megaprojects evaluation on sustainable development theory, where such developments are considered along environmental sustainability. It has been applied in understanding long-term strategic management, especially in the face of climate change, and how such development strategies support sustainable quality development (Pratono, 2021; Martensson et al., 2023). The principles of SDT are incorporated into frameworks such as the United Nations Sustainable Development Goals (SDGs), from which it is empirically adopted to premise and anchor models for corporate sustainability initiatives and environmental management systems across the globe (Sawin & Wallentin, 2019).

2.1.2 Triple Bottom-Line Model

The Triple Bottom-Line Model suggests that businesses should not only focus on financial profits but should also focus on two additional bottom lines: social and environmental performance (Elkington, 1994; Gimenez, 2012). Due to the nature of environmental resources that support businesses, strategic managers should balance between economics, society, and the environment (Longoni & Cagliano, 2016; Bohlmann et al., 2018). The model asserts that economic prosperity is essential; however, it is not sufficient for all societal well-being (Skouloudis et al., 2009). It argues that businesses should consider their impact on society and the environment alongside financial profits (Farooq et al., 2021), which enhances the competitiveness and innovation of a country. For instance, a business may consider innovative green products that save the environment while improving living standards. It also suggests that businesses should strive to create positive social impacts, including job creation, community development, and fair labor practices (Lozano, 2015; Miemczyk & Lucini, 2019). For instance, companies integrate TBL principles into their operations by measuring and reporting their social and environmental impacts together with financial results (Braccini & Margherita, 2018; Birkel et al., 2019). Thus, the tenets of the model often involve producing sustainability audits, adopting sustainable practices, and engaging with stakeholders. It provides a comprehensive framework for examining the interactions between competitiveness and innovation of a corporation (Literal & Guhao, 2021; Mattera & Gava, 2021).

2.2 Empirical Review

The empirical literature examining the relationships between competitiveness, innovation, and carbon taxation strategic adaptation reveals a complex landscape of findings that vary significantly across different contexts, methodologies, and regional settings. This section synthesizes the existing evidence base to understand how these key variables interact in practice.

2.2.1 Competitiveness and Innovation

The competitiveness and innovation capacity of an economy can influence how businesses respond to carbon taxation (Bigerna et al., 2023). Industries with higher innovation capabilities may adapt more readily because of their capacity to invest in cleaner technologies and processes as a strategy to reduce their carbon footprint (Huber et al., 2019). On the other hand, the competitiveness of certain industries, particularly those with high energy consumption, may be adversely impacted by

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carbon taxation (Leining et al., 2019). These could contribute to their potential resistance and hence lobby against strategic adaptation to carbon taxation (Guo et al., 2019).

2.2.2 Carbon Taxation Strategic Adaptation

Carbon taxation strategic adaptation involves the proactive adjustment and refinement of carbon pricing policies (Ghazouani et al., 2020). It also involves the establishment of strategies and approaches to enhance policy effectiveness, efficiency, and social acceptability (Hai-Tao et al., 2023). Carbon taxation strategic adaptation can therefore increase the rate of attainment of climate mitigation objectives and address broader socioeconomic considerations (Feindt et al., 2021). It encompasses a range of actions and measures aimed at optimizing policy design, implementation, and outcomes that respond to changing environmental, economic, social, and political dynamics (Fankhauser et al., 2013).

2.2.3 Competitiveness and Innovation, and Carbon Taxation Strategic Adaptation

Yang et al. (2022) researched China's fiscal and taxation policy for new energy vehicle industry technological innovation. Panel data of 14 listed new energy vehicle companies from 2012 to 2019. An entropy weight method was used to obtain the innovation index from indicators. These indicators include research and development, fixed asset investment, intangible assets, and patent application volume. Fiscal subsidies and tax burdens were independent variables. A fixed-effect model was used to analyze the impact of fiscal and taxation policies on technological innovation. The findings of the studies showed mixed outcomes. Financial subsidies were shown to encourage technological innovation among new energy vehicle manufacturers. Tax burden did not impact technological innovation. Technological innovation among new energy vehicle makers was also enabled by the scale and age of the enterprise, and the proportion of R&D personnel to that of all employees. The study specifically investigated technology innovation uptake. However, the proposed study has expanded the concept, and while there are several aspects of technology innovation, green technology innovation is one of the core moderating indicators in the relationship between socioeconomic factors and carbon taxation. Still, the proposed study will systematically review the concept and the influence of green technology on strategic adaptation to carbon taxation. This will further widen knowledge, which then can facilitate ease of technology adoption in the face of carbon pricing policies.

Zhang et al. (2022) investigated the presence of co-benefits of regionally differentiated carbon pricing policies across China. The study adopted spatial correlation analysis, multi-regional dynamic computable general equilibrium, and an extended response surface model with polynomial functions. Data were extracted from 2005 to 2019 for spatial cluster-level data. The outcome of the tests indicated that China is on track to achieve its 2030 CO2 targets with a 2060 target on-site for complete neutrality. However, the study also showed that regionally differentiated efforts led to increased carbon emission reduction compared to the national policy. The findings also showed that the reductions correlated with improved human health benefits. Contextually, this study was conducted in China, a developing but industrious nation, which has taken measures to reduce its emissions. Therefore, countries struggling to establish concrete emissions reduction strategies can borrow comprehensive review lessons, not only from China but from other countries too. This is the aim of the proposed study, especially for the developing economies in Africa.

Ali and Kirikkaleli (2023) sought to establish the relationship between carbon taxes, resource efficiency, and environmental sustainability in a developed country. The phenomenon was studied in France between 1995 and 2020. Novel Fourier autoregressive distributed lag cointegration was used for cointegration. Non-linear autoregressive distributed lag was used to estimate the long-run effect. Resource efficiency was found to be negatively correlated with environmental pollution. Still, the carbon tax impacted environmental pollution negatively. Lastly, the findings showed that energy use and economic growth positively influenced environmental pollution. Carbon taxes were found to achieve sustainable development goals and resource efficiency. The majority of the studies, including this one, have assessed various concepts on environmental taxes and sustainable development through series or panel data. This study will investigate these phenomena using the PRISMA model to extensively combine, analyze, and collectively interpret the relationship between carbon taxation, environmental sustainability, and socioeconomic factors. This can inform policy and practice to implement carbon pricing policies that are empirically proven.

Tian et al. (2023) wondered how technological innovation influences carbon neutrality from the perspective of the spatial spillover effect and attenuation boundary. Panel data was used to determine the relationship between the concepts. The dynamic spatial Durbin model and its moderating effect model were used. There was a noticeable variation in the spillover effect of technological innovation on carbon neutrality from heterogeneous technological sources. The study also revealed that foreign investments and introductions measurably moderated the impact on the carbon deficit. However, domestically purchased technological innovation has a negligible impact on carbon neutrality. The study specifically focused on carbon neutrality and how it is influenced by technological innovation spillover effects. The focus applies to those countries that are technologically advanced. It is necessary, thus, to investigate these effects on countries that depend on imported technologies. It is also important to increase the knowledge in the areas investigated by expanding from carbon neutrality to reduced emissions, from foreign investment to other macroeconomic effects, and from confined areas to a global or regional perspective. This will further strengthen policies and approaches to reducing emissions, especially for developing economies.

3.0 Methodology

This study was underpinned by a pragmatist research philosophy, which was oriented toward solving practical problems and was highly applicable when the research aimed to address real-world issues such as competitiveness and innovation, carbon taxation, and strategic adaptation (Yiaueki, 2023). The philosophy was flexible in its methodological approach since it allowed for the use of mixed methods to gain a comprehensive understanding of the research problem, which aligned with the use of both qualitative and quantitative approaches in systematic literature review and meta-analysis (Wilson, 2023). The pragmatist framework provided a robust foundation for analyzing complex socio-economic and environmental data with relevance for informing policy on the influence of competitiveness and innovation on carbon taxation policies (Katzav, 2023).

The study adopted a systematic review with meta-analysis design of literature on the phenomenon of carbon taxation strategic adaptation and its relationship with socio-economic factors and sustainability initiatives. This approach was selected to compile all empirical evidence meeting predetermined eligibility criteria to address the specific research question (Pahlevansharif et al., 2019). The systematic review involved a comprehensive literature search of multiple databases to

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ensure all relevant studies were included and screened for review, while the meta-analysis provided quantitative synthesis through statistical combination of results from multiple studies to yield more precise estimates of effects or relationships (Cho & Kim, 2024). Data were gathered from peer-reviewed journals published between 1990 and 2024 in English language only, with this period selected because the first known carbon tax was implemented in Finland in 1990. The eligibility criteria included studies covering various socioeconomic groups and industries affected by carbon taxation, focusing on topics such as innovativeness and competition, macroeconomic effects, environmental effectiveness, distributional implications, carbon pricing, political feasibility, carbon tax rates, carbon offset programs, green technologies, and stakeholder engagement across diverse geographical contexts.

Materials included in the analysis were extracted from Web of Science and Scopus databases using a detailed search criterion that included a search string with Boolean operators combining all study variables. The search string was framed as "socio-economic factors" OR "economic competitiveness" OR employment OR "labor productivity" OR "foreign direct investment" OR GDP OR "carbon dividend" OR "economic growth" OR "CO2 emissions" OR "greenhouse gas emissions" OR "GHG per capita" OR "carbon-intensive goods" OR inequality OR "labor market" OR "capital allocation" OR "co-benefits") AND ("strategic adaptation" OR "carbon pricing" OR "carbon tax" OR "carbon tax rates" OR "climate policy" OR "political feasibility" OR "climate strategy" OR "emission trading" OR "cap-and-trade" OR "carbon taxation"). Two reviewers were engaged in the initial screening and full-text screening using Covidence software, with a third reviewer used to resolve conflicts in the screened studies (Lorenc et al., 2016). The study assessed risk of bias using the Cochrane Risk of Bias Tool and ROBINS-I for risk of bias assessment, and Newcastle-Ottawa Scale and JBI Critical Appraisal Checklist for quality assessment, with poor quality studies managed by adopting a robust Bayesian hierarchical model to down-weight poor quality studies and correct for biases (Cumpston et al., 2019).

4.0 Results and Findings

This section presents the findings of the meta-analysis examining the relationship between competitiveness and innovation and carbon taxation strategic adaptation. The results are organized to provide a comprehensive overview of the descriptive characteristics, effect size analysis, heterogeneity assessment, and subgroup analysis of the included studies.

4.1 Study Characteristics and Descriptive Statistics

The descriptive analysis aimed to characterize the included studies and examine the distribution of effect sizes across different contexts and methodological approaches. This analysis provided essential baseline information about the composition of the evidence base and the variability of findings across studies.

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Table 1: Descriptive Statistics of Included Studies

Characteristic	Value
Observations (effects) [n]	16
Unique studies [k]	13
Effect size (yi) - mean	0.026
Effect size (yi) - sd	0.115
Effect size (yi) - median (IQR)	-0.016 (0.073)
Effect size (yi) - min/max	-0.184 / 0.322
SE: mean	0.032
Variance: mean	0.0026
Year: min / median / max	2018 / 2022 / 2024
Sign: % negative / % zero / % positive	68.8% / 0.0% / 31.2%

A total of 13 unique studies were included in the analysis, yielding 16 observed effect sizes. The geographical distribution revealed a concentration of studies in Asia (68.8%, n=11), followed by Europe (25.0%, n=4), and Africa (6.2%, n=1). China dominated the sample with 37.5% of studies, while Pakistan and the EU each contributed 12.5%. The remaining studies originated from South Korea, France, Vietnam, Egypt, India, and the EU-15 countries, each representing 6.2% of the sample. Publication years ranged from 2018 to 2024, with a median publication year of 2022. Methodologically, panel regression models and autoregressive distributed lag (ARDL) approaches were most frequently employed (18.8% each), followed by interaction models (12.5%). Sample sizes across studies varied considerably, ranging from 43 to 580 observations, with the majority clustering between 108 and 136. The descriptive statistics revealed important patterns in the effect size distribution. The mean effect size was 0.026, while the median was -0.016 with an interquartile range of 0.073. The standard deviation of 0.115 indicated substantial dispersion relative to the central tendency, with effect sizes ranging from -0.184 to 0.322. The distribution of effect directions showed that 68.8% of studies reported negative effects, 31.2% reported positive effects, and none reported zero effects, suggesting that while a majority of studies found downward pressure on competitiveness and innovation from carbon taxation, a substantial minority identified positive or neutral impacts.

4.2 Meta-Analysis Results and Heterogeneity Assessment

The meta-analysis was conducted to synthesize the quantitative findings across studies and assess the overall effect of carbon taxation on competitiveness and innovation outcomes. The

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heterogeneity assessment was performed to understand the consistency of findings across different study contexts and methodological approaches.

Table 2: Meta-Analysis Results and Heterogeneity Assessment

Statistic	Value
k (number of effect sizes)	16
Pooled effect (μ)	-0.014
Standard Error (SE)	0.005
95% CI Lower	-0.024
95% CI Upper	-0.005
τ^2 (between-study variance)	0.000204
Q statistic (df)	50.15 (15)
I^2 (%)	70.087
Prediction Interval	[-0.044, 0.015]

The random-effects meta-analysis revealed a small but statistically significant negative pooled effect of $\mu = -0.014$ (SE = 0.005; 95% CI -0.024 to -0.005; $z = -2.91$; $p = 0.004$). This negative coefficient indicates, on average, a small downward association between carbon taxation implementation and competitiveness and innovation outcomes, including employment, total productivity, and foreign direct investment. The corresponding fixed-effect estimate was $\mu\_FE = -0.016$ (95% CI -0.020 to -0.012; $p = 2.2\times10^{-12}$), demonstrating consistency between analytical approaches while acknowledging the presence of heterogeneity. The heterogeneity assessment revealed substantial between-study variance that extended well beyond sampling error. Cochran's $Q(15) = 50.15$ ($p \approx 1.1\times10^{-5}$) indicated significant heterogeneity, with an estimated between-study variance of $\tau^2 = 0.000204$. The I^2 statistic of 70.1% confirmed substantial heterogeneity, suggesting that study contexts, policy designs, exposure levels, and measurement approaches explained a large proportion of the dispersion around the mean effect. The 95% prediction interval of -0.044 to 0.015 was particularly informative, indicating that in comparable future settings, true effects could range from modestly negative to near-zero or even slightly positive, underscoring the context-dependent nature of carbon taxation effects.

4.3 Subgroup Analysis by Geographic Region

Subgroup analysis was performed to explore potential sources of the observed heterogeneity by examining whether effects varied systematically across different geographic regions. This analysis aimed to identify whether regional differences in economic development, policy frameworks, or institutional contexts influenced the relationship between carbon taxation and competitiveness and innovation outcomes.

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Table 3: Subgroup Analysis by Geographic Region

Region	k	Pooled Effect	SE	95% CI Lower	95% CI Upper
Asia	11	-0.013	0.007	-0.027	0.000
Europe	4	-0.014	0.009	-0.032	0.004
Africa	1	-0.021	0.009	-0.038	-0.004

The subgroup analysis showed relatively consistent negative effects across regions: Asia (k=11) demonstrated a pooled effect of $\mu = -0.013$ (95% CI -0.027 to 0.000), Europe (k=4) showed $\mu = -0.014$ (95% CI -0.032 to 0.004), and Africa (k=1) exhibited $\mu = -0.021$ (95% CI -0.038 to -0.004). A formal between-groups test using a common τ^2 yielded Q - between(2) = 0.15 ($p = 0.926$), indicating no statistically significant evidence that average effects differed by region once heterogeneity was accounted for. The analysis revealed that the small negative average effect with wide dispersion was consistent across regions, suggesting that many contexts cluster near zero with some negative skew and a minority showing slightly positive effects. This pattern aligns with theoretical expectations that transitional competitiveness pressures from carbon taxation can be offset or overcome through well-designed policy features such as predictable implementation schedules, targeted safeguards for energy-intensive trade-exposed sectors, and complementary innovation policies. These findings support established research demonstrating that innovation responses can be positive when carbon price signals are credible, as evidenced in the EU Emissions Trading System where regulated firms increased low-carbon patenting by approximately 10% without crowding out other technologies (Dechezleprêtre et al., 2022).

5.0 Conclusion

This meta-analysis examined the relationship between competitiveness and innovation and carbon taxation strategic adaptation across 13 unique studies with 16 effect sizes. The findings revealed a small but statistically significant negative pooled effect ($\mu = -0.014$), indicating that carbon taxation implementation is associated with modest downward pressure on competitiveness and innovation outcomes. However, the substantial heterogeneity observed ($I^2 = 70.1\%$) and the wide prediction interval (-0.044 to 0.015) demonstrate that these effects are highly context-dependent and vary considerably across different policy designs, institutional frameworks, and economic conditions. The evidence suggests that transitional competitiveness pressures from carbon taxation are real but not universal, and can often be offset through well-designed policy architectures that incorporate credible implementation schedules, targeted safeguards for energy-intensive trade-exposed sectors, and complementary innovation support mechanisms. The substantial heterogeneity points to several key factors driving observed differences, including policy design credibility, sectoral exposure levels, access to finance, technological maturity, and baseline productivity levels. Two primary mechanisms reconcile the mixed findings: short-term risk and adjustment costs that compress margins for exposed firms, and directed technological change that enhances productivity and investment when carbon price signals are predictable and durable. The subgroup analysis revealed no significant regional differences, suggesting that policy design features matter more than geographic context in determining outcomes.

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The study's findings align with emerging evidence that competitiveness and innovation outcomes from carbon taxation are largely policy-determinable. When governments implement transparent, credible carbon pricing policies paired with targeted transition support and innovation incentives, competitiveness effects tend to cluster near neutral while innovation activity strengthens across the economy. This underscores the critical importance of adaptive policy design rather than blanket assumptions about carbon taxation's economic impacts, particularly for developing economies considering strategic adaptation to carbon pricing mechanisms.

6.0 Recommendations

Based on the meta-analysis findings, governments should implement transparent, inflation-indexed carbon tax rate schedules with built-in guardrails and periodic reviews based on clear performance indicators, while avoiding ad-hoc renegotiations and deploying temporary, targeted safeguards for energy-intensive trade-exposed activities, with revenue recycling strategies that prioritize productivity-enhancing activities including reductions in distortionary taxes and strengthening research and development ecosystems. Private sector actors should establish comprehensive competitiveness monitoring systems with sector-level diagnostic capabilities, standardized transition risk screening mechanisms, and time-limited conditional support programs, while integrating carbon price signals into core business processes and developing robust financing mechanisms for clean technologies with transparency dashboards for accountability. Future research should expand causal identification methodologies to examine firm-level outcomes under varying carbon tax implementation speeds, adopt study-cluster-robust meta-analytic approaches that quantify interactions between carbon pricing policies and complementary measures, and focus on developing evidence-based frameworks for adaptive policy design that can inform real-time adjustments to carbon taxation policies based on observed competitiveness and innovation outcomes, particularly in developing economy contexts where empirical evidence remains limited.

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