[*THE IMPACT OF THE EU ETS ON TECHNOLOGICAL INNOVATION FOR CLIMATE CHANGE MITIGATION FROM 2005 TO 2023*]

[Zihong Chen, Sustainability Research Institute, School of Earth and Environment, University of Leeds, +447529919055, eezch@leeds.ac.uk]
[Paul E. Brockway, Sustainability Research Institute, School of Earth and Environment, University of Leeds, P.E.Brockway@leeds.ac.uk]
[Sheridan Few, Sustainability Research Institute, School of Earth and Environment, University of Leeds, S.Few@leeds.ac.uk]
[Haoyu Zhang, Leeds University Business School, University of Leeds, H.Zhang13@leeds.ac.uk]
[Jouni Paavola, Sustainability Research Institute, School of Earth and Environment, University of Leeds, J.Paavola@leeds.ac.uk]

Overview

Addressing the escalating climate crisis necessitates the accelerated advancement of technological innovations for climate change mitigation (TICCM) (Dhakal et al., 2022). Environmental regulation is widely acknowledged as a pivotal driver of such advancements, supported by the Induced Innovation Hypothesis (IIH) and the Weak Porter Hypothesis (WPH) (Jaffe et al., 2002, 2005; Rennings, 2000; Rennings & Rexhäuser, 2011). Among regulatory mechanisms, emissions trading systems (ETSs), as market-based instruments, are particularly prominent for their cost-effectiveness and capacity to provide dynamic and sustainable innovation incentives (Jaffe et al., 2002; Liu et al., 2022; Rennings, 2000; Requate, 2005; Rogge et al., 2011).

A systematic review, however, reveals that current evidence on the relationship between ETSs and TICCM is incomplete, with most studies constrained by temporal lags and geographic scope (Chen et al., 2024). In particular, quantitative research on the European Union ETS (EU ETS)—the oldest system with the largest trading volume and value—is nearly absent for phases III (2013-2020) and IV(2021-2023), and available findings remain divergent. These research limitations underscore several critical and unresolved questions: How substantial has the impact of the EU ETS been on TICCM over nearly two decades? How do these impacts evolve dynamically across different phases of system development? Does technical and regional heterogeneity exist in these impacts? This study addresses these issues by offering a comprehensive quantitative investigation into the relationship between the EU ETS and TICCM. Our new insights provide empirical evidence for the effectiveness of ETSs in incentivizing technological innovation, while also contributing to the broader evidence base for IIH and WPH.

Methods

This study adopts a quasi-natural experimental design, leveraging the EU ETS as a policy intervention to quantitatively assess its impact on the number of patent applications for climate change mitigation technolohgies(CCMT). We apply the Sequential Synthetic Difference-in-Differences (SSDID) method, which integrates the features of the Synthetic Control Method (SCM) and Difference-in-Differences (DID) approaches and enables the assessment of the dynamic effects of staggered policy implementation (Serenini & Masek, 2024). A unique firm-level dataset was constructed by matching European Union Transaction Log (EUTL) accounts with firm identifiers from Orbis, identifying 12,106 firms ever constrained by the EU ETS.

Results

A pronounced surge in patent applications for CCMT by EU ETS-regulated firms was observed immediately after the system's implementation, followed by a sharp decline. From the start of Phase II (2009), annual patent applications stabilized at an average of 300. Empirical estimates indicate that the EU ETS increased patent applications by 0.053 on average, with statistical significance at the 90% confidence level. The dynamic impact assessment shows a phase-dependent pattern, with the strongest effects observed mid-phase and diminishing at the phase boundaries. Across Phases I, II, and III, the mean impact value shows a notable increase. Significant industry-region heterogeneity is evident, with pronounced positive effects in the manufacturing and energy supply sectors.

Conclusions

Overall, this study demonstrates that the EU ETS exerts a statistically significant yet modest positive impact on TICCM. The incremental and phase-dependent variation in impact reflects policy delays and evolving regulatory effectiveness. The findings also highlight pronounced industry and regional disparities, suggesting that certain sectors respond more strongly to regulatory incentives than others. By offering a long-term, comprehensive analysis of the EU ETS’s influence, this study contributes valuable insights for refining market-based environmental regulations to better support TICCM and achieve climate mitigation objectives.

References

Chen, Z., Brockway, P. E., Few, S., & Paavola, J. (2024). The impact of emissions trading systems on technological innovation for climate change mitigation: A systematic review. *Climate Policy*, *0*(0), 1–17. https://doi.org/10.1080/14693062.2024.2443464

Dhakal, S., Minx, J. C., Toth, F., Abdel-Aziz, A., Figueroa Meza, M. J., Hubacek, K., Jonckheere, I. G. C., Kim, Y.-G., Nemet, G. F., Pachauri, S., Tan, X. C., & Wiedmann, T.. (2022). Emissions Trends and Drivers. In A. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *IPCC, 2022: Climate change 2022: Mitigation of climate change. Contribution of working group III to the sixth assessment report of the intergovernmental panel on climate change* (pp. 215–294). Cambridge University Press. https://www.ipcc.ch/report/ar6/wg3/

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2002). Environmental policy and technological change. *Environmental and Resource Economics*, *22*(1), 41–70. https://doi.org/10.1023/A:1015519401088

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, *54*(2), 164–174. https://doi.org/10.1016/j.ecolecon.2004.12.027

Liu, Y., Liu, S., Shao, X., & He, Y. (2022). Policy spillover effect and action mechanism for environmental rights trading on green innovation: Evidence from China's carbon emissions trading policy. *Renewable and Sustainable Energy Reviews*, *153*, 111779. Scopus. https://doi.org/10.1016/j.rser.2021.111779

Rennings, K. (2000). Redefining innovation—Eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319–332. https://doi.org/10.1016/S0921-8009(99)00112-3

Rennings, K., & Rexhäuser, S. (2011). Long-term impacts of environmental policy and eco-innovative activities of firms. *International Journal of Technology, Policy and Management*, *11*(3–4), 274–290. https://doi.org/10.1504/IJTPM.2011.042087

Requate, T. (2005). Dynamic incentives by environmental policy instruments—A survey. *Ecological Economics*, *54*(2), 175–195. https://doi.org/10.1016/j.ecolecon.2004.12.028

Rogge, K. S., Schneider, M., & Hoffmann, V. H. (2011). The innovation impact of the EU Emission Trading System—Findings of company case studies in the German power sector. *Ecological Economics*, *70*(3), 513–523. Scopus. https://doi.org/10.1016/j.ecolecon.2010.09.032

Serenini, R., & Masek, F. (2024). Spatial Synthetic Difference-in-Differences. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4736857