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Beyond Emissions : Assessing the Impact of Carbon Taxes on Investment and Technological Progress

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Beyond Emissions: Assessing the Impact of Carbon Taxes on Investment and Technological Progress

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Abstract

This paper investigates empirically how the macroeconomic impact of climate policies, such as a carbon tax, differs across GDP/employment growth, investment, and innovation. Using a local projection approach, we find evidence of a slight negative effect of the carbon tax on investment in Europe, which peaks at longer lags. Notably, countries that do not engage in revenue recycling face stronger negative impacts on investment. Our point estimates suggest a zero short- and long-run impact on total innovation, implying that taxation alone does not drive technological advancements. Our results help explain the previously observed neutral effects of carbon taxes on GDP and employment growth. Our findings imply that reductions in emissions would likely be greater if the carbon tax is combined with other climate policies (e.g., R&D and green investment subsidies) rather than simply increasing the carbon tax to achieve similar emission targets.

Keywords: Carbon taxes; Transition Risks; Technological Innovation, European Emission Trading System.

JEL classification: E23, E24, H23, Q54, Q58

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1 Introduction

The escalating climate crisis necessitates robust policy interventions to mitigate greenhouse gas emissions. Economists have for decades recommended that carbon dioxide and other greenhouse gases be priced to provide incentives for their reduction (Metcalf, 2009; Nordhaus, 2019). The two most direct mechanisms for implementing a carbon price are a carbon tax and a cap-and-trade system. However, the empirical evidence regarding the macroeconomic impacts of carbon pricing remains scarce, with even less clarity on its broader implications. Most analyses were more typical event study methods used in microeconomic assessments¹ rather than on the macroeconomic time-series econometric methods. But more recently, Metcalf and Stock (2023), conducts a macroeconomic impact of the Europe’s carbon tax on economic growth, employment and industrial employment growth.

While the existing macroeconomic studies examine the implications of growth - or employment - neutral carbon taxes, it is important to address a few points regarding efficiency. First, it is undeniable that carbon pricing—whether implemented as a carbon tax or through a cap-and-trade system—entails efficiency costs. By effectively taxing inputs used in the production process, carbon pricing can lead to distortions in investment decisions and innovation activities. Another critical concern is transition risk—the potential macroeconomic disruptions that may arise from a sudden shift to a low-carbon economy. For instance, when regulated firms face higher costs on polluting emissions relative to other production inputs, this can influence their capital investment decisions.

Alternatively, such firms may be incentivized to adopt operational changes and undertake investments aimed at reducing the emissions intensity of their output. Moreover, innovation is widely acknowledged as a primary driver of economic growth in modern economies. By increasing the cost of carbon-intensive activities, carbon taxes create economic incentives for firms to innovate and adopt cleaner technologies. Recent empirical evidence underscores the role of carbon pricing in accelerating technological progress (e.g. Martin et al., 2014a; Dechezleprêtre et al., 2018; Garcia-Quevedo et al., 2022).

1. This identification challenge is particularly complex because numerous factors can simultaneously influence behavior, potentially confounding the impact estimate. The primary difficulty in this analysis lies in isolating the causal effects of the carbon taxes from those of confounding factors that also affect the outcomes of interest.

The consideration of transition risk and cost efficiency raises questions about how existing carbon tax policies influence investment and innovation decisions. Given that, in this paper, we look at the macroeconomic impact of the Europe’s carbon tax but by using this time investments and innovation (number of patents filed). Understanding the transmission mechanisms of carbon tax shocks is crucial for firms, as it helps them navigate policy changes and optimize strategic decisions. This insight is also key to designing effective and sound climate policies.

In our paper, we consider the general innovation not only in (clean innovation) low-carbon patenting (carbon patents filed)². We also analyze 31 European countries participating in the EU-wide Emissions Trading System (EU-ETS). In this group, 15 countries implement a carbon tax, primarily targeting emissions not covered by the EU-ETS. By focusing on countries within the EU-ETS, we can isolate the marginal effect of carbon taxes on investment, and total innovation by exploiting the heterogeneity in carbon tax regimes across this group.

To isolate the effect of the carbon tax from responses driven by changes in the tax that are not anticipated by past values of the tax or other macroeconomic variables, we adopt the approach of [Metcalf and Stock \(2023\)](#). Specifically, we assume that variations in the carbon tax unrelated to historical local economic and financial conditions, as well as to current and past international economic shocks, can be treated as exogenous. Under this identification strategy, the dynamic causal effects of a change in the carbon price can be estimated using local projections, controlling for relevant economic factors.

In this paper, using a local projection approach, we find that while the implementation of carbon taxes in Europe leads to a slight decline in investment rates, this effect dissipates over time. Similarly, our analysis finds a zero impact of carbon taxes on total innovation, suggesting that carbon tax alone does not drive technological advancements. Countries that do not engage in revenue recycling face stronger negative impacts on investment, highlighting the importance of fiscal policy design in shaping the economic consequences of carbon tax policy. Since economic growth is partially driven by the investment rate, particularly through firms’ cost-efficiency considerations, our findings offer a potential explanation for the near-zero impact of a carbon tax on growth and total employment, as documented by [Metcalf and](#)

2. Another important avenue of research is examining whether clean innovation displaces dirty innovation ([Popp and Newell, 2012](#)), as this could have implications for macroeconomic growth. We propose that this issue can be addressed by analyzing the entirety of patents filed as innovation.

Stock (2023). Additionally, given that innovation is a key driver of modern economic growth, our results help explain why carbon taxes appear to have no discernible effect on long-term growth. However, our findings underscore the importance of complementary policies, such as R&D and green investment subsidies, to enhance innovation incentives and mitigate potential investment distortions,—rather than relying solely on increasing carbon taxes to achieve similar emission reduction targets.

Related literature. This paper contributes to the expanding literature on the economic impacts of climate policy, with a particular focus on carbon pricing. While a growing body of research demonstrates the effectiveness of these policies in reducing emissions (e.g. Metcalf, 2009; Martin et al., 2014b; Andersson, 2019), evidence on their broader economic implications remains relatively limited. However, the existing literature has examined its effects on macroeconomic outcomes such as growth and employment. For instance, Metcalf (2009) and Metcalf and Stock (2023) and Känzig and Konradt (2024) use either local projections or SVAR found broadly an emissions reduction and no adverse impacts of the tax on economic or employment growth. Building on this foundation, this paper considers firms’ cost efficiency and the transition risk hypothesis to better understand how carbon taxes influence firms’ investment and innovation decisions. By doing so, it highlights the critical role of policy design in shaping firms’ responses and explores the broader implications for policymakers and the management of transition risks.

There are several theoretical papers that analyze transition risk, by focusing on the risk caused by policy shocks from carbon tax within the environmental DSGE models (Carattini et al., 2023; Diluio et al., 2021; Carattini et al., 2024). In this paper, we seek to quantify the empirical impact of Europe’s carbon tax on investment and innovation. The “induced innovation” hypothesis, originally proposed by Sir Hicks, John R. (1932) and later revisited in the context of environmental policy by Porter (1991) and Acemoglu et al. (2012), posits that a portion of this new investment will be allocated toward the development and commercialization of emissions-reducing technologies³. Recent microeconomic empirical evidence highlights the role of carbon pricing in driving technological innovation (e.g. Martin et al., 2014a; Deche-

3. A large and expanding body of theoretical or empirical research is focused on understanding and quantifying the relationship between environmental policies and directed technological change, with innovation often measured at the levels of economic sectors, countries, or firms (Newell et al., 1999; Brunnermeier and Cohen, 2003; Aghion et al., 2012, among others). For recent surveys on this topic, see Popp (2010), and Ambec et al. (2013). However, none of them in the literature have examined the macroeconomic impact of carbon taxes, particularly in relation to investment or innovation.

zleprêtre et al., 2018; Garcia-Quevedo et al., 2022). Their findings from European firms indicate that industries subject to carbon pricing exhibit a significant increase in environmentally friendly patenting activity. In this study, we extend the analysis to the macroeconomic level by examining the impact of carbon tax on overall innovation, without distinguishing between clean and dirty technologies. This approach allows us to assess its implications for transition risk and firms’ cost efficiency.

The remainder of this paper is organized as follows: Section 2 describes the sample data. Section 3 explains the methodology used to estimate the carbon tax shock and local projection (LP) approach. Section 4 presents the results. Section 5 presents further analysis. Lastly, section 6 concludes.

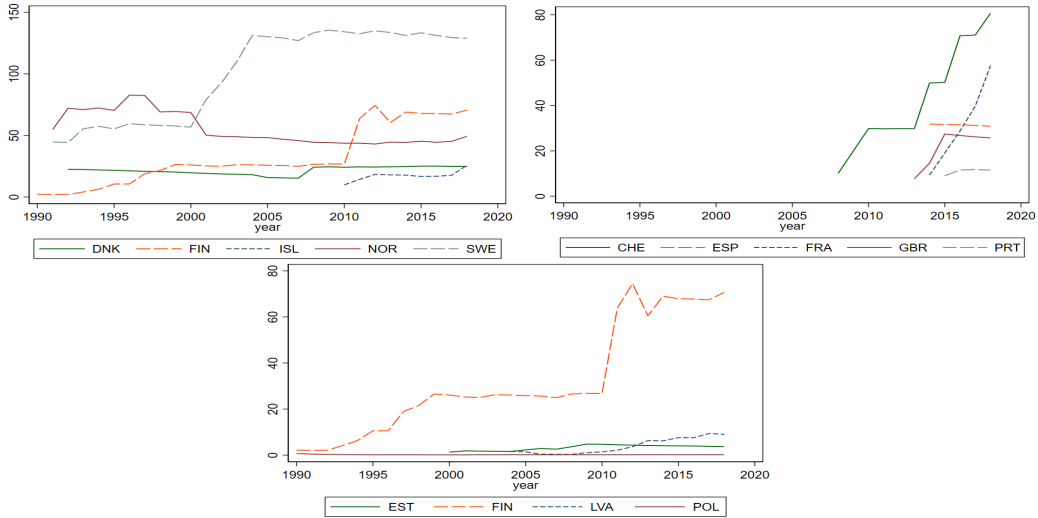
2 Data

We consider 31 European countries participating in the EU-wide Emissions Trading System (EU-ETS), included UK. In this group, 15 countries implement a carbon tax, primarily targeting emissions not covered by the EU-ETS. Table A1 in the Appendix provides an overview of carbon tax policies across the selected countries. The ETS was introduced in 2005 with a pilot phase (Phase I), followed by Phase II (2008–2012) and Phase III (2013–2020). Figure 1 illustrates the evolution of carbon tax rates in EU countries since their introduction, highlighting significant heterogeneity both in tax rates and in the time of enactment.

Finland was the first country to introduce a carbon tax in 1990, starting at a relatively low rate and progressively increasing over time, particularly in the 2010s, reflecting its commitment to strengthening carbon pricing. Sweden followed in 1991, gradually increasing its tax rate to become one of the highest in the world. Denmark and Norway both introduced carbon taxes in 1992, with Norway steadily raising its rates while Denmark saw some fluctuations, likely due to policy adjustments and economic considerations.

Switzerland implemented its carbon tax much later, in 2008, with a steady upward trajectory, suggesting a gradual tightening of carbon pricing policies. The United Kingdom introduced a carbon tax in 2013, significantly later than the early adopters, with an initial moderate rate that remained relatively stable. France, which implemented its carbon tax in 2014, steadily increased the rate in the following years. Spain, also a late adopter in 2014, maintained a relatively low tax rate compared to other European nations, reflecting a more cautious approach to carbon pricing.

Figure 1 – Evolution of Real Carbon Tax Rates Over Time



Notes: Real rates are expressed in local currency and adjusted to 2018 USD. Country codes: Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Iceland (ISL), Ireland (IRL), Latvia (LVA), Norway (NOR), Poland (POL), Portugal (PRT), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), and the United Kingdom (GBR).

Estonia introduced its carbon tax in 2000, starting at a low rate and gradually increasing it over time. Across all countries, a general trend of gradual increases in tax rates is evident, particularly in early adopters like the Nordic countries and Switzerland. In contrast, late adopters such as France and the UK implemented carbon taxes at moderate initial rates but increased them more rapidly. Variability in tax rates across countries highlights differences in political and economic factors influencing carbon pricing strategies. Countries that introduced carbon taxes earlier have had more time to refine their policies, leading to structured and often higher tax rates, whereas newer adopters have adjusted more aggressively to align with climate policy objectives⁴.

Figure 2 shows investment rate and innovation (patents filed) before and after each country's enactment of the carbon tax. From the Figure 2(a) and 2(b), the dots which indicate mean values show a slight (less than 1%) decrease in the level investment rate and innovation following an the time of enactment of carbon tax but overall there seem to be no clear pattern in changes of both investment and

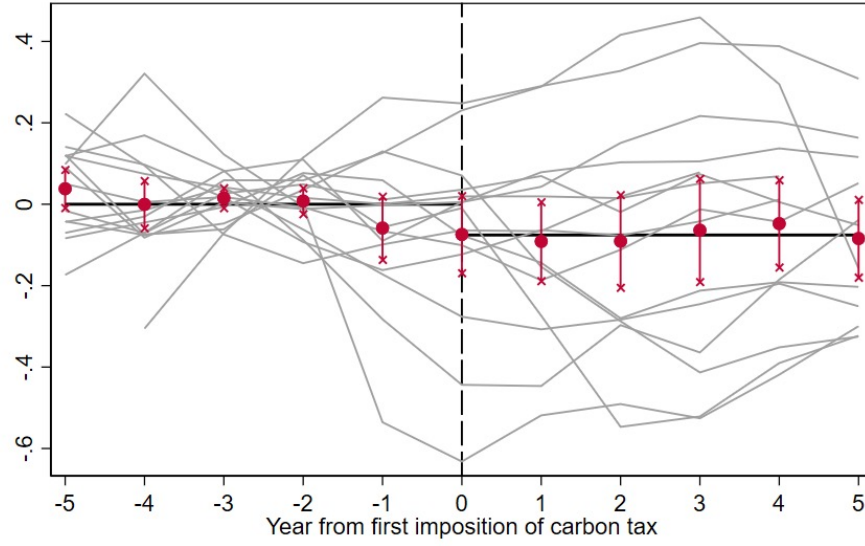
4. We refer the readers to [European Commission \(2015\)](#) for further details.

innovation following the enactment of carbon tax.

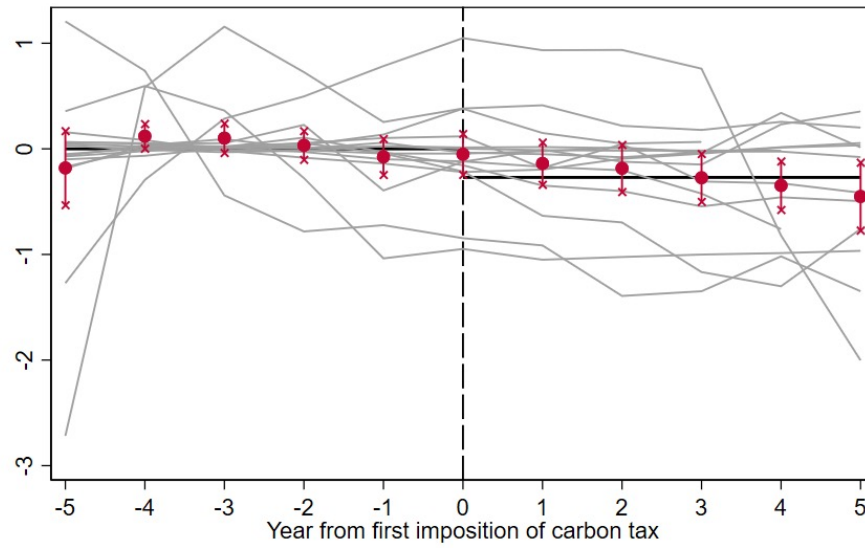
Our analysis leverages data from multiple sources. Our data on investment as a percentage of GDP is taken from the IMF World Economic Outlook. Data on innovation, measured by the number of patents filed, is obtained from the World Intellectual Property Organization (WIPO). Real GDP and carbon tax rates are drawn from the [World Bank Group \(2019\)](#), while employment statistics are derived from the EU Eurostat database. Information on the share of greenhouse gas emissions subject to carbon taxation is also sourced from the [World Bank Group \(2019\)](#). Additionally, data on country-level carbon dioxide emissions from fuel consumption, covering the period from 1990 to 2018, are sourced from Eurostat. Our analysis focuses on carbon dioxide emissions resulting from fuel combustion in road transport, the commercial and institutional sectors, and the household sector, as these are the primary sectors typically subject to national carbon taxation policies.

Figure 2 – Event study analysis of Carbon tax implementation

(a) Investment rate (in % of GDP)



(b) Innovation (Total number of patents filed)



Notes: Deviated from country's pretax mean. Horizontal lines are pre/post means. Dots and bars denote mean and 90 percent confidence interval by year.

3 Identification and Estimation

To identify the effect of the tax from the response to changes in the tax that are not predicted by past values of the tax or other macroeconomic variables, we follow [Metcalf and Stock \(2023\)](#), and assume that a carbon tax as having two components: one responding to historical economic and financial factors, the other being unpredicted by past economic and financial factors. Changes in the latter component may include tax adjustments based on pre-determined legislative schedules, shifts in ambition reflecting the environmental priorities of the ruling party, or reactions to international climate policy pressures. Our identifying assumption is that these changes—those unrelated to historical local economic and financial factors or current and past international economic shocks—can be considered exogenous. Under this assumption, it is possible to estimate the dynamic causal effects to a change in the carbon price using local projections when including the relevant economic controls. Following [Metcalf and Stock \(2023\)](#), we include carbon prices and taxes in real coverage-weighted terms, deflating them using the relevant GDP deflator and weighting by the country-specific ETS and carbon tax emission coverage. Specifically, we estimate impulse response functions (IRFs) to carbon tax shocks up to the horizon H using [Jordà \(2005\)](#)'s local projections (LP) :

$$y_{i,t+h} - y_{i,t-1} = \alpha + \Gamma_h \tau_{it} + \beta(L) \tau_{i,t-1} + \delta(L) \Delta \chi_{i,t-1} + \gamma_t + \mu_{it} \quad (1)$$

where $y_{i,t+h}$ is either investment or innovation and emissions, τ_{it} is the coverage-weighted real carbon tax rate for country i at date t , and Γ_h is the effect of an unexpected change in the carbon tax rate at time t on annual investment or innovation h periods hence. The vector $\chi_{i,t-1}$ includes our control variables such as $\ln(\text{GDP})$, $\ln(\text{total employment})$, $\ln(\text{manufacturing employment})$, and the GDP price deflator. Including controls other than past investment or innovation contributes to identification and should provide assurance that our model satisfies the assumption of invertibility. This implies that the impacts of carbon policies should be proportional to their overall tax burden.

All regressions include both country and year fixed effects. In theory, under our exogeneity assumption, the inclusion of year effects should not be strictly necessary. However, we include them for two key reasons. First, since all the countries in our sample are European, they face shared political pressures that could lead to common changes in carbon prices, as well as exposure to common economic shocks. These shared influences, even if exogenous, could act as confounding factors. Therefore, we identify the effect of carbon tax increases using country-level surprises in carbon prices while controlling for these common trends through year effects. Second,

even if year effects are not essential for identification, their inclusion can help account for common macroeconomic shocks—such as the 2009 global recession—which may improve estimation precision by reducing standard errors. Standard errors are heteroskedasticity-robust (Plagborg-Møller and Wolf, 2021).

To validate our findings, we also estimate bivariate panel local projections (LP) and structural vector autoregressions (SVARs), using the tax rate, investment, and innovation as dependent variables⁵. These regressions include four annual lags of each variable as regressors, along with country and year fixed effects. This approach extends the standard time series SVAR framework to a panel setting. The identification assumptions remain consistent with those employed in the corresponding bivariate LP regressions. We use the SVAR estimator as a robustness check for the LP estimator, and standard errors for the SVAR are calculated using a parametric bootstrap method.

We also employ a long-run identification framework to assess the standard theoretical assumptions underlying computable dynamic equilibrium models of carbon taxes. These models typically posit that the long-run growth rate is determined by economic fundamentals, which remain unaffected by the relative price changes induced by a carbon tax. Specifically, we test whether the carbon tax has no long-term effects on investment or innovation. If this holds true, the carbon tax may impact investment and innovation in the short run but would eventually converge back to the long-run growth rate over time. We estimated the multivariate and bivariate LP and bivariate SVAR specifications both with this zero long-run growth effect restriction imposed (“restricted” case) and not imposed (“unrestricted”)⁶.

5. We then evaluate the counterfactual scenario of a one-time permanent \$40 increase in the carbon tax, applied to a tax with a coverage rate of 30 percent of the country’s emissions—approximately equal to the average coverage rate observed in the sample.

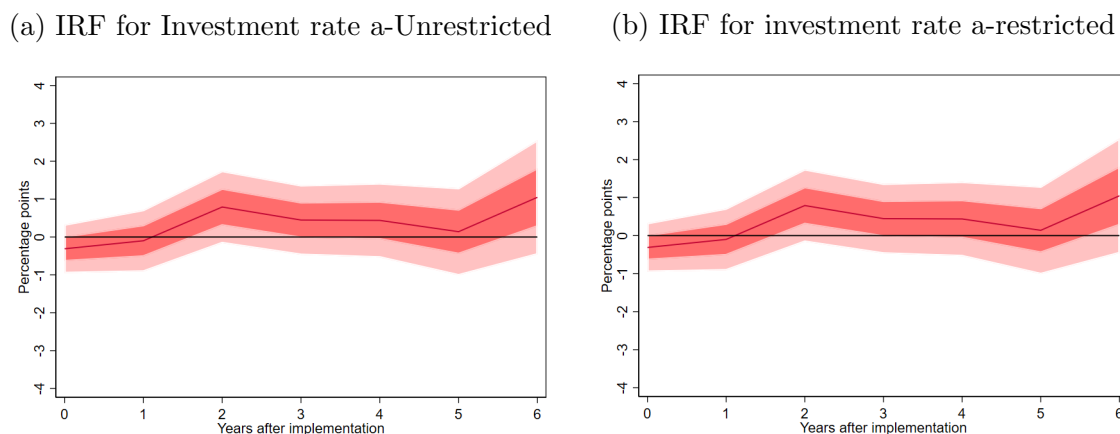
6. Since the LP approach computes impulse responses up to a finite horizon h as specified in equation (1), it does not directly estimate the long-term effect at arbitrarily distant horizons. Therefore, in the LP test of the long-run restriction, we approximate the long-term effect using the response at the eight-year horizon.

4 Results

4.1 Investment rate

Figure 3 documents the dynamic effect on GDP growth of a \$40 permanent increase in the carbon tax, covering 30 percent of emissions, estimated by LP using all 31 countries over the full 1985–2018 sample. We consider two identification schemes : first, under unrestricted model, that is, the model that allows for a nonzero long-term effect of the tax on investment rate; second under unrestricted model in which a zero long-term effect of the tax rate on GDP growth is imposed. Under Identification I, Figure 3a documents a modest decline (below 1%) in the investment rate following the carbon tax shock with a slightly increase after 2 year following the shock. Similarly, under Identification II, Figure 3b shows the same patterns like under the identification I, suggesting that the estimated response remains within one standard deviation of zero.

Figure 3 – Effect on investment rate of a carbon tax shock

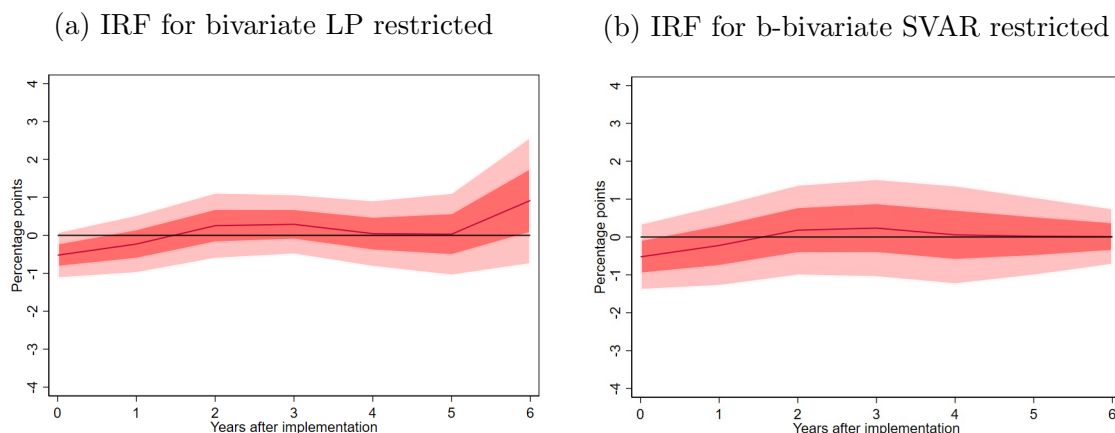


Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

Figure 4 replicates the dynamic response of the investment rate documented in Figure 3, but estimated using a bivariate panel local projection (LP) model (Figure 4a) and a structural vector autoregression (SVAR) framework (Figure 4b), both under the restricted specification. The bivariate LP estimates closely mirror those obtained from the multivariate LP model in Figure 3, while the results from the bivariate

ate LP and SVAR approaches exhibit a high degree of concordance. Both methodologies indicate a modest contraction in the investment rate—below 1%—following a carbon tax shock, suggesting that the estimated effect is robust across identification strategies.

Figure 4 – Effect on investment rate of a carbon tax shock



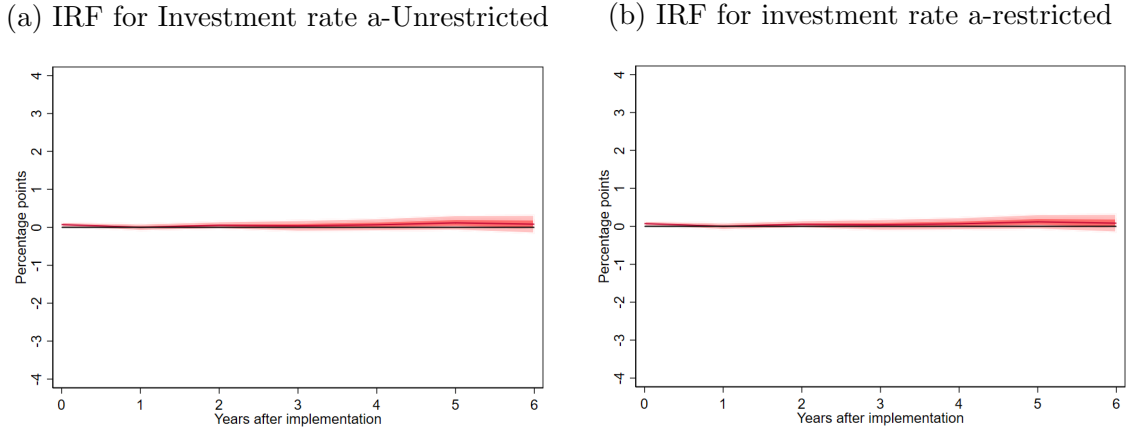
Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

The results presented in Figures 3 and 4 do not provide evidence of substantial negative effects of a carbon tax on investment rate as they also do not support the assertion that such a tax imposes significant negative economic consequences. Since economic growth is partially driven by the investment rate, particularly through firms' cost-efficiency considerations, our findings offer a potential explanation for the near-zero impact of a carbon tax on growth, as documented by [Metcalf and Stock \(2023\)](#). The observed marginal decline in the investment rate following a carbon tax shock suggests that firms may adjust capital expenditures in response to increased production costs, potentially offsetting any growth-enhancing effects of the tax. This raises an important policy question: should policymakers implement complementary measures to mitigate these potential distortions rather than relying solely on further increases in the carbon tax? In the next section, we assess the extent to which an increase in the carbon tax influences the investment dynamics across European economies.

4.2 Total innovation

Figure 5 shows dynamic effects for the innovation. In both Identification schemes (the unrestricted and restricted cases), innovation displays a zero impact following a carbon tax shocks. In this paper we consider total innovation, without differentiating between green and dirty technologies as it captures the overall trajectory of technological advancement, reflecting firms' responses to carbon tax incentives and provides a broader understanding of how innovation drives productivity and economic growth. While distinguishing between green and dirty innovation is important for environmental policy, examining total innovation helps policymakers assess whether interventions are affecting the overall rate of technological progress. It also offers a more consistent measure for evaluating structural transformations in economies over time, given that transitions between technological paradigms may not always be captured by sector-specific analyses. Furthermore, since many macroeconomic analyses rely on aggregate patent data, this approach provides empirical robustness, as classification biases in distinguishing between types of technologies can distort conclusions⁷.

Figure 5 – Effect on innovation of a carbon tax shock



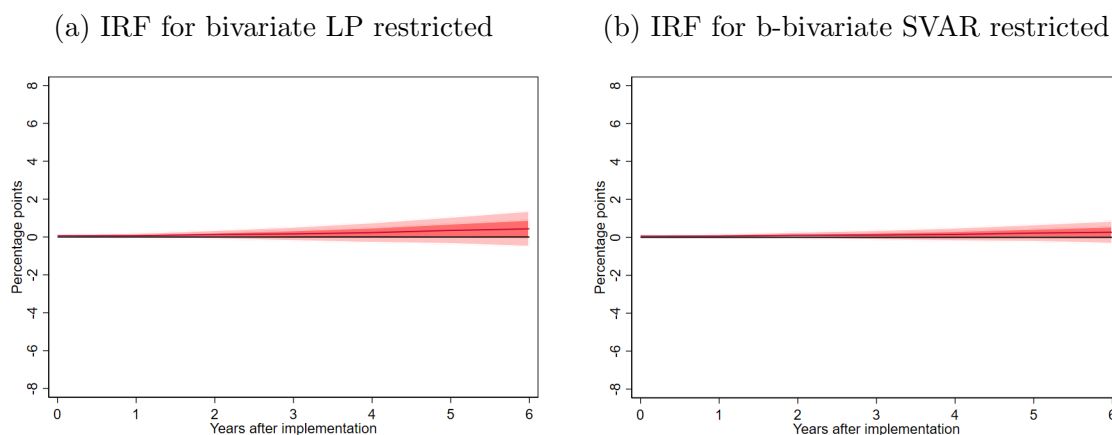
Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

Figure 6 revisits the dynamic response of the investment rate shown in Figure 5,

7. We leave to future research to investigate whether this zero impact would support innovation shifting from dirty to green as total innovation is not affected. However, in this paper, we find no significant impact across all time horizons of the carbon tax on total innovation

but applies alternative estimation methods: a bivariate panel local projection (LP) model (Figure 6a) and a structural vector autoregression (SVAR) model (Figure 6b), both using the restricted specification. The bivariate LP results align closely with those from the multivariate LP model in Figure 3, while the bivariate LP and SVAR estimates exhibit strong consistency. Both approaches indicate no significant impact on total innovation following a carbon tax shock, suggesting that the effect is robust across different identification strategies.

Figure 6 – Effect on innovation rate of a carbon tax shock



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

As innovation is widely acknowledged as a key driver of growth in modern economies, our findings offer a potential explanation for why carbon taxes appear to have no effect on growth, as observed by [Metcalf and Stock \(2023\)](#). Specifically, it seems that the carbon tax itself has little to no impact on innovation — our proxy for technological change—thereby limiting its potential to drive economic growth. Based on this result, we also argue that understanding these effects allows policymakers to design complementary measures, rather than simply increasing the carbon tax—which has been shown not to incentivize innovation. Measures such as subsidies for green R&D can help maximize the innovation potential of carbon taxes while mitigating with the transition risks.

5 Further analysis

In this section, we explore several potential explanations for the observed variations in the effects of carbon tax. Specifically, we examine the impact of revenue recycling, the influence of higher carbon tax rates and the potential for nonlinear effects such as whether its impact varies with the level of carbon tax rate, the proportion of emissions covered, or the state of the economy (boom vs. bust)⁸

5.1 Revenue recycling

We examine whether the impact of the carbon tax on the investment rate or total innovation is more pronounced in countries that have signaled their intention to recycle carbon tax revenues through reductions in income or payroll taxes. Given the positive correlation between investment and consumption (Tobin, 1965), we argue that an increase in household consumption—driven by lower income or payroll taxes—could incentivize firms to invest more in response to rising demand. Building on the framework of Metcalf and Stock (2023)⁹, we classify Denmark, Sweden, Norway, Finland, Switzerland, and Portugal as a subgroup of jurisdictions that engaged in partial or full revenue recycling by utilizing carbon tax proceeds to lower pre-existing income tax rate. Accordingly, we examine whether the effect of carbon tax on investment rates and innovation is more pronounced within this subgroup of countries compared to the broader set of jurisdictions that have implemented carbon taxes.

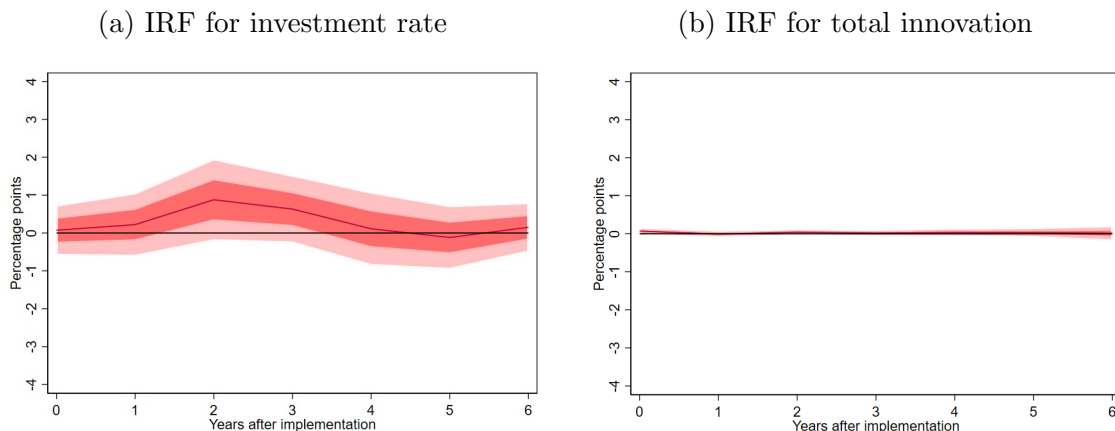
Figure 7 presents the dynamic effects of carbon tax on the investment rate (panel a) and innovation (panel b) for countries that implemented revenue recycling. Panel 7(a) reveals that the economic impact of carbon taxes was smaller in these countries, with investment rates remaining positive over a four-year period, though the initial response was weaker compared to the full sample (Figure 3a), especially during the first three years. This suggests that recycling tax revenues may alleviate some of the negative effects on investment. Panel 7(b) shows that the impact on total innovation

8. We also checked whether the results are unchanged when we do not include year fixed effects. Thus, our results are not affected by the possibility of cross-country spillovers. These results are available upon request.

9. Several pioneering jurisdictions, including Denmark, Sweden, Norway, and Finland, implemented carbon tax within the broader framework of Green Tax Reforms aimed at alleviating distortions associated with marginal income taxation. Switzerland adopted a similar approach by explicitly allocating two-thirds of its carbon tax revenues to reductions in direct taxation. Likewise, Portugal integrated carbon tax revenue recycling into its fiscal strategy.

is statistically insignificant in both the short and long run, with coefficients close to zero, implying that carbon taxes alone did not significantly drive technological change. These findings suggest that while revenue recycling may mitigate investment distortions, it does not appear to stimulate aggregate innovation, highlighting the need for additional policy measures, such as targeted R&D subsidies, to maximize the innovation potential of carbon taxes.

Figure 7 – Effect of a carbon tax shock for revenue recycling countries



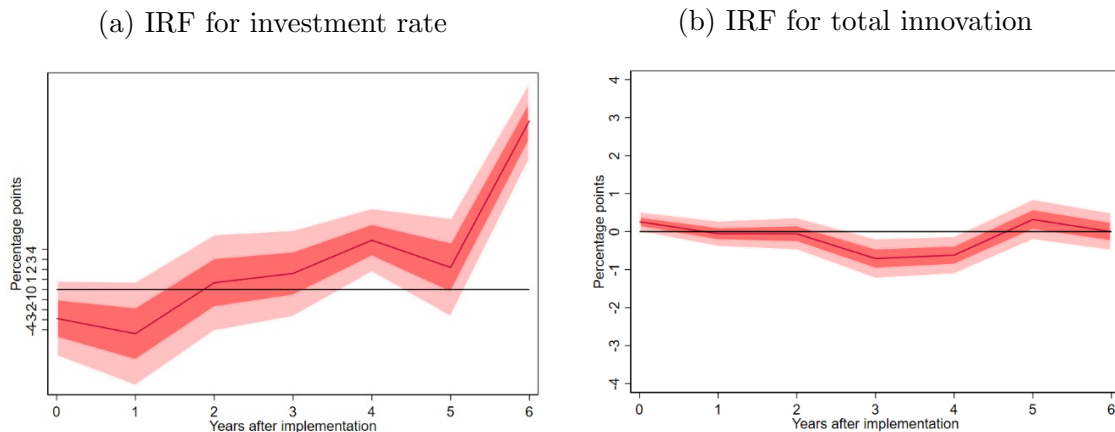
Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

An alternative approach to addressing this question is to examine the group of countries that do not engage in revenue recycling. This subgroup is notably larger, and it may reveal more pronounced differences in outcomes. By focusing on these countries, we can investigate whether the absence of tax revenue recycling leads to distinct patterns in investment and innovation.

Figure 8 illustrates the responses of the investment rate and total innovation in non-revenue recycling countries following a carbon tax shock. Panel 8(a) reveals a significant decline in the investment rate, falling by up to 3 percent immediately after the tax shock, before gradually recovering over the next two years. This initial drop suggests that the absence of revenue recycling exacerbates the negative short-term effects on investment, as firms may face higher costs without the compensatory benefits of tax cuts or other fiscal incentives. In contrast, Panel 8(b) shows that the impact on total innovation remains statistically indistinguishable from zero, with the coefficients strongly suggesting no significant change. These results indicate that,

similar to the revenue-recycling countries, carbon taxes alone do not seem to drive meaningful shifts in innovation. Accordingly, this also suggests that complementary policies, may be necessary to foster innovation alongside carbon tax.

Figure 8 – Effect of a carbon tax shock for non-revenue recycling countries

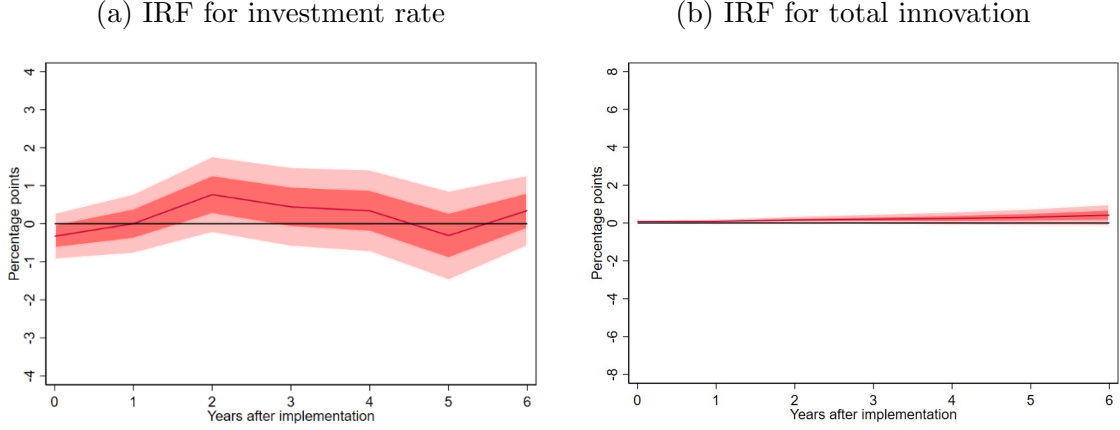


Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

5.2 Large carbon tax countries

We investigate whether the impact of carbon tax on the investment rate and total innovation is more pronounced in countries with higher carbon tax rates, holding all other factors constant. Figure 9 presents the dynamic responses of the investment rate and total innovation in countries with relatively high carbon tax rates following a tax shock. In panel 9(a), the effects on the investment rate closely mirror those observed in the full sample (Figure 3a), showing a slight decline in investment, which suggests that the impacts are not significantly different from those in the full sample. Similarly, the impact on total innovation, depicted in panel 9(b), is also in line with the full sample results, indicating that the effect remains statistically insignificant, with the coefficients close to zero. These results suggest that, regardless of the tax rate level, carbon taxes alone do not appear to have a meaningful impact on innovation. This underscores the need for complementary policies, such as targeted R&D incentives and green investment subsidies, to stimulate technological advancements and maximize the potential benefits of carbon tax, particularly in high-tax jurisdictions.

Figure 9 – Effect of a carbon tax shock for large carbon tax countries



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors.

5.3 Nonlinear Effects

We also investigate the potential nonlinearities in the effect of a carbon tax by examining whether its impact varies with the tax rate, the proportion of emissions covered, or the state of the economy (boom vs. bust). To capture these dynamics, we employ a local projections (LP) framework to estimate how the response of our key variables changes under different specifications. In the first specification A, the LP regression is augmented by the square of the share-weighted tax rate, (τ_{it}^2) and its lags, so that the marginal effect on either investment or total innovation depends linearly on the level of the share-weighted tax. In the second specification, the LP regression is augmented by the share-weighted tax rate interacted with the share, $\tau_{it}s_{it}$, and its lags, so that the dynamic effect of a given tax increase depends on the coverage share s_{it} . In the third specification, we explore the cyclical sensitivity of the carbon tax effect by interacting the share-weighted tax rate with lagged GDP growth to check whether there is evidence that the carbon tax has a different impact during a boom than a bust. Figures A1 and A2 present the IRFs for the effect of a carbon tax increase on investment and innovation, assuming a tax covering 30% of emissions, with a \$20 increase in the left panel and a \$100 increase in the right panel. Figures A3 and A4 explore the second nonlinear specification, examining a \$40 tax increase under coverage shares of 20% (left panel) and 50% (right panel). Figures A5 and A6 investigate the third nonlinear specification, assessing how the tax impact varies across macroeconomic conditions. Specifically, we compare the effects when

GDP growth is at the 10th percentile, representing an economic downturn (bust), and at the 90th percentile, indicative of an expansionary phase (boom).

With few exceptions, the nonlinear dynamic effects remain largely consistent, both statistically and economically, with those derived from the linear specifications, typically falling within a standard error range. Additionally, we find no strong evidence that the impact of a carbon tax differs significantly between low-growth (bust) and high-growth (boom) economic environments. An exception arises in the investment and total innovation IRFs for a marginal increase in the carbon tax coverage share under specification A (Figure A3, left panel, and Figure A4, left panel). In this case, investment increases by up to 2.5% after eight years, while patenting activity (innovation) declines at a similar rate.

6 Conclusion

Economists have for decades recommended that carbon dioxide and other greenhouse gases be priced to provide incentives for their reduction. Among these interventions, carbon tax has emerged as a pivotal tool. While existing literature has examined its effects on macroeconomic outcomes such as growth and employment, understanding its impact on investment and innovation remains underexplored yet crucial. This essay underscores the importance of estimating the empirical effects of carbon taxes on these domains, emphasizing their relevance for policymakers and the management of transition risks. A deep understanding of how firms respond to carbon tax is essential for guiding improvements to the EU ETS and optimizing the design of emerging carbon pricing schemes in other parts of the world.

Thus, this paper investigate the macroeconomic effects of carbon tax in Europe, focusing on its impact on investment and innovation. Using a local projection approach, our findings suggest that while carbon taxes induce a slight decline in investment rates, this effect turns slightly positive after several years. Moreover, we find no zero impact of carbon taxes on total innovation, implying that carbon tax alone does not drive technological advancements or encourage patenting. These results suggest a proposal explanation of why that carbon pricing mechanisms do not generate strong adverse effects on GDP or employment. Furthermore, our analysis suggests that the economic effects of carbon tax may depend on how tax revenues are utilized. Countries that engage in revenue recycling experience milder positive impacts on investment, highlighting the importance of fiscal policy design in shaping the economic consequences of climate policies.

While carbon taxes provide incentives to reduce emissions (showed in [Metcalf and Stock \(2023\)](#)), they do not appear to meaningfully stimulate innovation or long-term capital investment. This underscores the need for complementary policies, such as targeted R&D subsidies, green investment incentives, production tax credit for qualifying renewable power sources, and revenue recycling mechanisms, to mitigate potential investment distortions and enhance the innovation potential of carbon pricing. Our results support the theoretical findings of [Acemoglu et al. \(2012\)](#), which indicate that using a carbon tax to both reduce current emissions and shape future research can create significant distortions. This suggests that optimal policy should rely less on a carbon tax and focus more on directly promoting the development of clean technologies¹⁰.

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10. Given the emerging practice of automated rebating based on firm performance, we recommend that policymakers consider implementing similar schemes to optimize carbon tax strategies. By offering rebates on emissions tax payments contingent on firms’ progress toward intensity-based performance standards, jurisdictions can effectively combine a price on emissions with subsidies for intensity reduction. This approach not only encourages firms to reduce emissions but also allows for achieving the same environmental outcomes at a lower carbon price [Böhringer et al. \(2023\)](#)

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A Appendix A : Greenhouse Gas Emission Tax

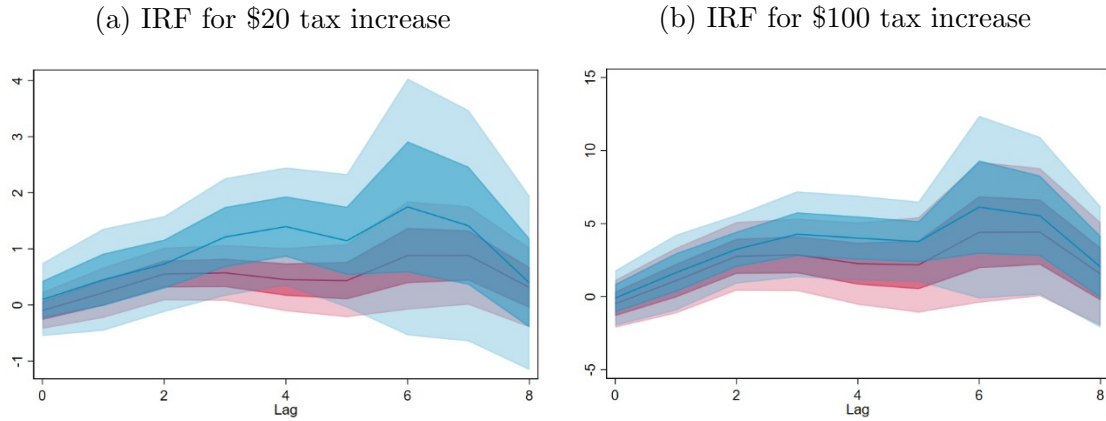
Table 1 – Greenhouse Gas Emission Tax Information

Country	Year of Enactment	Rate in 2018 (US\$ per metric ton)	Intended Revenue Recycling?	Share of Greenhouse Gas Emissions in 2019 Covered by Tax
Denmark (DNK)	1992	24.92	Yes	40%
Estonia (EST)	2000	3.65	No	3%
Finland (FIN)	1990	70.65	Yes	36%
France (FRA)	2014	57.57	No	35%
Iceland (ISL)	2010	25.88	No	29%
Ireland (IRL)	2010	24.92	No	49%
Latvia (LVA)	2004	9.01	No	15%
Norway (NOR)	1991	49.30	Yes	62%
Poland (POL)	1990	0.16	No	4%
Portugal (PRT)	2015	11.54	Yes	29%
Slovenia (SVN)	1996	29.74	No	24%
Spain (ESP)	2014	30.28	No	3%
Sweden (SWE)	1991	128.91	Yes	40%
Switzerland (CHE)	2008	80.70	Yes	33%
UK (GBR)	2013	25.71	No	23%

Source : [World Bank Group \(2019\)](#) and [Metcalf and Stock \(2023\)](#). Notes : Coverage is share of a country emissions covered by carbon tax.

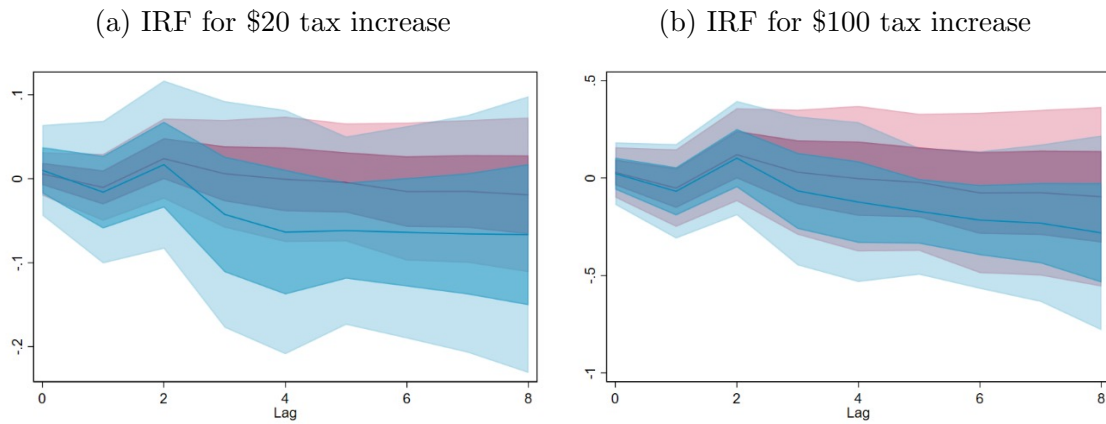
B Appendix B: Nonlinear Effects

Figure 10 – Dynamic effect on investment for the change in the level of carbon tax



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).

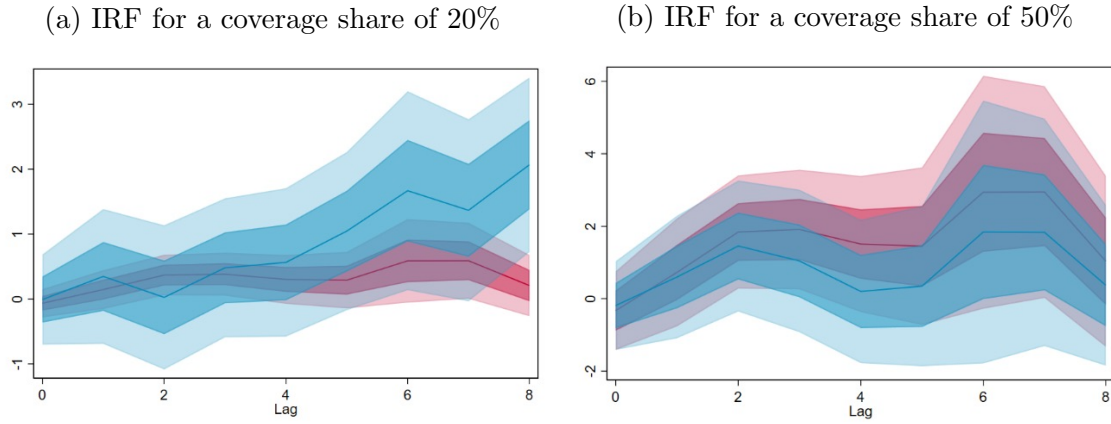
Figure 11 – Dynamic effect on investment for the change in the level of carbon tax



Notes: The solid line is the point estimate and the dark and light shaded areas are

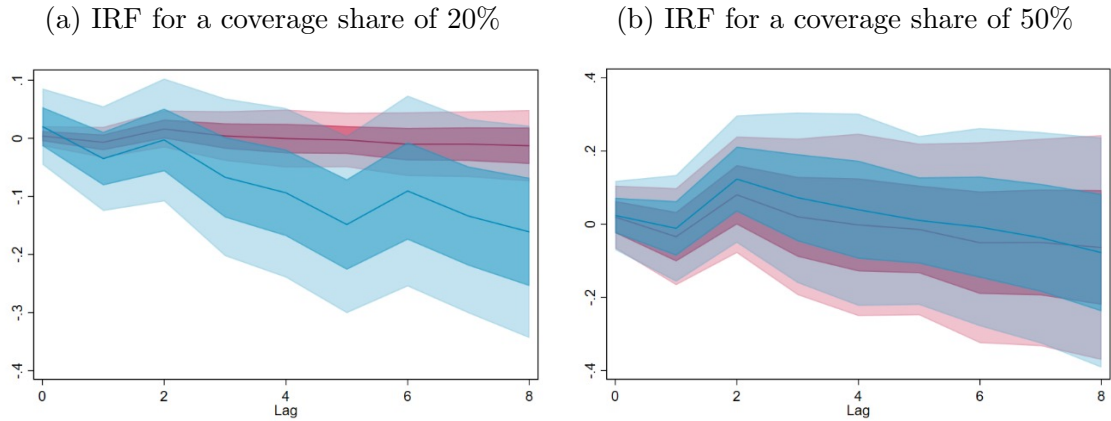
68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).

Figure 12 – Dynamic effect on investment for the change in the coverage share



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).

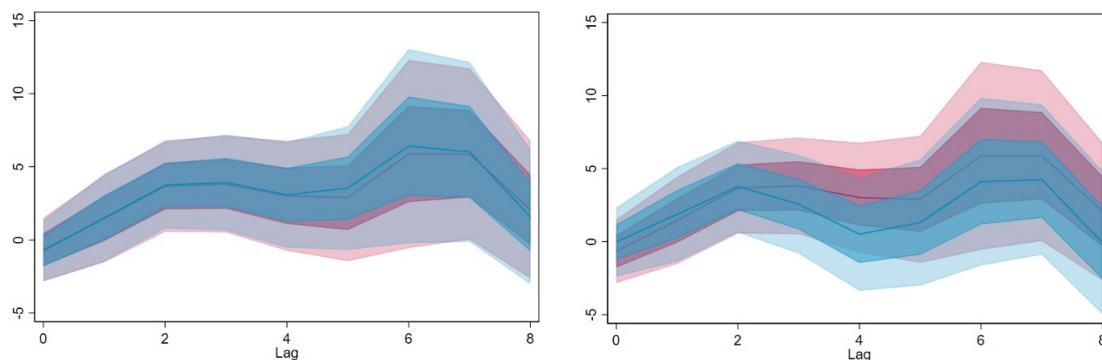
Figure 13 – Dynamic effect on total innovation for the change in the coverage share



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).

Figure 14 – Dynamic effect on investment for the change in economic conditions

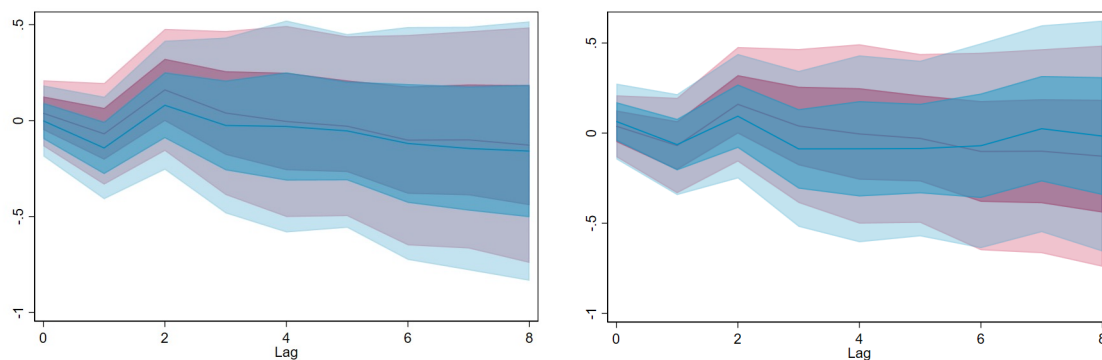
(a) IRF for a 10th percentile for GDP growth (b) IRF for 90th percentile for GDP growth



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).

Figure 15 – Dynamic effect on total innovation for the change in economic conditions

(a) IRF for a 10th percentile for GDP growth (b) IRF for 90th percentile for GDP growth



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively. Includes four lags of all regressors. The nonlinear regressions shade confidence bands in blue and are plotted along with the linear specification bands (in red).