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**Working Paper**

## Cross-border transmission of climate policies through global production networks

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# Cross-border Transmission of Climate Policies Through Global Production Networks\*

## Abstract

Climate policies do not operate in isolation but propagate through global production networks, affecting industries beyond national borders. This paper combines international input-output data with a granular instrumental variable approach to capture how foreign regulations transmit through upstream and downstream linkages. Distinguishing between market-based policies, non-market regulations, and technology support, the analysis shows that foreign climate policies can enhance domestic productivity, with effects shaped by industry characteristics and operating through technological adjustment along supply chains. The results underscore the importance of accounting for international spillovers when evaluating the economic impact of environmental regulation.

*Keywords: climate policy, environmental regulations, global value chains, green innovation, international trade, productivity*

*JEL classification: F18, L16, O44, Q37*

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# 1 Introduction

The transition to a low-carbon economy depends not only on the ambition of national climate policies but also on how these policies reverberate through global production networks. Because industries are embedded in complex cross-border supply chains, regulations adopted in one country can affect productivity and competitiveness abroad. Stricter vehicle emission standards in Germany may raise compliance costs for foreign suppliers of auto parts, while renewable energy subsidies in Japan can stimulate demand for clean energy equipment from foreign producers. Such examples illustrate a broader point: environmental regulation is set locally but its economic consequences are international.

Evidence from other contexts suggests that such propagation is quantitatively important. A growing body of research shows that physical shocks propagate through production networks, depressing output for both directly affected firms and their suppliers and customers (Barrot and Sauvagnat 2016, Carvalho and Tahbaz-Salehi 2019), sometimes with cross-border spillovers (Boehm et al. 2019, Zappalà 2025). More recent work documents that environmental regulation also travels through domestic supply chains, shaping costs, innovation, and productivity within national economies (Franco and Marin 2017, Lin et al. 2024, Benincasa et al. 2024). Yet systematic evidence on whether climate policies propagate internationally through supply chains is still limited. Dechezleprêtre and Kruse (2022) provide an early contribution, but their coarse measures and short-run focus find little evidence of cross-border effects. This paper fills that gap by providing empirical evidence that foreign climate policies affect domestic industries through international production linkages, offering a new perspective on how regulation shapes productivity across borders.

To examine whether and how climate policies propagate internationally, I use international input-output data for 44 industries in 40 countries from 1995 to 2020 to trace how changes in foreign policy stringency affect domestic industries via supplier and customer linkages. A central challenge is endogeneity, since regulation may respond to economic conditions. To address this, I apply a granular instrumental variable approach in the

spirit of Gabaix and Koijen (2021, 2024), exploiting the fact that foreign exposures are highly concentrated in a small set of industries. Idiosyncratic policy changes in these industries generate quasi-random variation in exposure that can be used to identify the effects of foreign climate policy transmission.

In addition to analyzing climate policy stringency as a whole, I also distinguish between three broad categories of policies: market based instruments, non market regulations, and technology support measures. Separating these types is important, since they affect firms through different channels and may therefore generate different patterns of international spillovers. Beyond aggregate productivity effects, I further examine the mechanisms through which foreign climate policies shape outcomes along supply chains, with particular attention to innovation and the adoption of existing technologies.

I show that foreign climate policy stringency generates positive productivity effects through international supply chains, with propagation more pronounced along upstream linkages. The gains are driven mainly by market based instruments and technology support policies, while non market regulations play a limited role. These effects are concentrated in manufacturing industries, particularly in sectors that are more polluting, more directly subject to regulation, more internationally integrated, and more upstream in the production network. Taken together, the results indicate that climate policy spillovers extend beyond directly regulated firms and shape broader patterns of productivity across borders.

The concentration of gains in polluting, internationally integrated, upstream, and strictly regulated industries suggests that these are precisely the settings where firms face both stronger pressure and greater scope to adjust. While the heterogeneity analysis cannot identify the exact channels, the pattern is consistent with two mechanisms emphasized in the literature: the development of new green technologies through innovation and the uptake or diffusion of cleaner inputs through adoption.

To shed light on these mechanisms, I examine how foreign climate policies influence both the development of new technologies and the uptake of existing ones along supply chains. The innovation channel is particularly relevant, as previous studies have shown

that environmental regulation can stimulate green technological change within national supply chains (Lin et al. 2024, Franco and Marin 2017). I build on this literature by using data on green patents to trace how foreign regulatory exposure shapes domestic innovation outcomes. At the same time, I consider the adoption and diffusion of existing technologies, which may arise as firms adjust input choices in response to regulations faced by their international partners. Distinguishing between these channels provides insight into how international spillovers of climate policy translate into sustained productivity gains.

The findings are robust to a wide range of alternative specifications. They hold when exposure is constructed using value added linkages rather than intermediate input shares, which avoids potential double counting. The results also remain stable under alternative definitions of production networks, including configurations that reflect long run averages and thus permit some adaptation of trade relationships. Consistent positive responses appear across different productivity measures, including both real and nominal indicators from multiple data sources. In addition, the results are not sensitive to alternative lag structures in the local projection framework, indicating that the documented gains reflect stable dynamic responses rather than artifacts of model specification.

The contribution of the paper is multifaceted. It shows that climate policies act as a distinct class of shocks that propagate internationally through supply chains, reshaping productivity beyond directly regulated firms. It further demonstrates that these spillovers vary systematically across policy types and industry characteristics, with market based instruments and technology support measures driving the gains in sectors that are more polluting, more internationally integrated, and more upstream in the production network. Finally, it highlights the mechanisms behind these effects, pointing to the roles of both innovation and the adoption of cleaner inputs in the international transmission of climate policy. Beyond academic debates, the results underscore that the effectiveness of climate regulation cannot be assessed solely within national borders, but requires a perspective that accounts for international production linkages and cross-border spillovers.

The remainder of the paper is structured as follows. Section 2 reviews the related lit-

erature. Section 3 describes the construction of foreign climate policy exposure through production linkages. Section 4 presents the data. Section 5 contains the empirical analysis, including the identification strategy, baseline results, heterogeneity analysis, mechanisms, and robustness checks. Lastly, Section 6 concludes.

## 2 Literature Review

Climate risk is commonly divided into two categories: physical risk, arising from extreme weather events and natural disasters, and transition risk, arising from policy and regulatory efforts to mitigate climate change. Both types of risk may propagate through production networks, but the empirical literature has focused primarily on physical risks.

A first set of contributions examines how physical shocks propagate within national economies. Barrot and Sauvagnat (2016), focusing on the United States, document that output losses from natural disasters are transmitted downstream from directly affected suppliers to their customer firms. Palepu et al. (2025) report similar evidence, emphasizing that the extent of propagation depends on network position: downstream firms with greater centrality are better able to buffer negative shocks. Evidence from the Great East Japan Earthquake of 2011 further highlights the importance of production linkages. Carvalho et al. (2021) show that disruptions spread in both upstream and downstream directions, and estimate that the earthquake reduced Japanese GDP by 0.47 percentage points, compared to 0.21 percentage points in the absence of network linkages.

A second body of work considers whether physical shocks also transmit internationally. Here the evidence is more mixed. Zappalà (2025) find that agricultural heat shocks reduce supply availability and raise input costs, generating negative downstream effects across borders. Boehm et al. (2019) provide related evidence from the 2011 Japanese earthquake, showing that U.S. firms reliant on Japanese suppliers were unable to substitute away from disrupted inputs, leading to substantial output losses. Bao et al. (2024) show that extreme weather events affect export decisions, particularly in trade-intensive industries such as French wine production. By contrast, Kashiwagi et al. (2021), studying Hurricane Sandy



in 2012, conclude that propagation occurred primarily through domestic linkages, with little evidence of international spillovers. Together, these findings indicate that physical shocks can transmit across borders through production networks, but the strength of propagation depends on the nature of the shock and the industries involved.

Evidence on transition risks, and in particular the supply chain effects of climate policy, is more limited. Benincasa et al. (2024) show that California’s cap-and-trade program raised costs for regulated suppliers and increased the emissions intensity of their customers’ supply chains within the United States. Related theoretical work suggests that regulation can spur innovation along supply chains, both upstream and downstream, rather than only within directly regulated firms (Greaker 2006, Heyes and Kapur 2011). Empirical evidence, however, remains confined to domestic contexts. Lin et al. (2024) document for China that stricter environmental regulation induces positive spillovers, as suppliers facing customers under greater regulatory pressure increase their green patenting activity. Franco and Marin (2017), analyzing manufacturing sectors across several European countries, also restrict attention to domestic input-output relationships. They find that downstream environmental stringency is the main driver of both innovation and productivity, while within-sector regulation affects productivity only. Taken together, these studies demonstrate that climate policies propagate along supply chains in divergent ways, amplifying costs in some contexts while stimulating innovation in others, but without accounting for international transmission.

The study of Dechezleprêtre and Kruse (2022) is perhaps closest to the present paper. They examine the effect of climate policy stringency on green innovation and economic performance, incorporating supply chain weights to allow for propagation through production networks. Their results suggest that stricter policies raise mitigation patents at the firm level, but they do not find evidence of spillovers through supply chain linkages, nor of broader productivity or competitiveness gains. Several differences are noteworthy. First, their analysis is conducted at the firm level but relies on country-sector supply chain weights, effectively assigning the same link structure to all firms within an industry. Second, their identification strategy emphasizes short run effects, while my approach

traces medium run dynamics where productivity responses are more likely to materialize. Finally, unlike their treatment of supply chains, I explicitly distinguish between foreign and domestic linkages and revisit these contrasts below when discussing exposure construction and results.

A further distinction concerns the mechanisms under consideration. Dechezleprêtre and Kruse (2022) focus narrowly on innovation, whereas I allow for a broader set of channels. Evidence from other contexts suggests that productivity gains can also arise from the adoption and diffusion of existing technologies. Adhvaryu et al. (2020) and Filippini et al. (2020) document efficiency improvements from energy-saving upgrades in Indian and Chinese manufacturing, while Mercure et al. (2025) highlight macro-level productivity effects of low-carbon transitions through diffusion and structural change in the United Kingdom. These findings indicate that adoption can complement innovation as a source of productivity improvements, motivating my exploration of both mechanisms in the international production network context.

In sum, the existing literature shows that production networks transmit physical shocks and, within national economies, climate policy shocks. What remains unclear is whether such transition risks also propagate internationally through production networks. This paper takes up that question by combining cross-country, industry-level input-output data with a granular identification strategy to assess the effects of foreign climate policies on domestic industries. In doing so, it connects insights from research on physical shocks, environmental regulation, and transition risks, but shifts the focus to the international propagation of climate policy.

### **3 Exposure to Foreign Climate Policy via Production Linkages**

I construct measures of climate policy exposure that capture how foreign environmental regulations propagate through global production networks. The approach builds on the theoretical and empirical foundations of network propagation in Carvalho and Tahbaz-

Salehi (2019) and Acemoglu et al. (2016), who demonstrate how shocks transmit upstream and downstream through input-output linkages. Methodologically, it is most closely related to Das et al. (2022), who use supply chain weights to trace the transmission of sectoral shocks both domestically and across borders. Conceptually, it also resembles Zappalà (2025), who interacts supply chain linkages with climate shocks. Using international input-output tables, I similarly trace how policy changes in one country affect industries abroad through the suppliers they rely on (upstream linkages) and the customers they serve (downstream linkages).

Formally, let industry  $j$  in country  $i$  source intermediate inputs from industry  $\ell$  in country  $k$ , denoted by  $II_{ij}^{k\ell}$ . The relative importance of this trade link is captured by the share of inputs from  $k, \ell$  in the total intermediate inputs of  $i, j$ :

$$\frac{II_{ij}^{k\ell}}{\sum_k \sum_\ell II_{ij}^{k\ell}}. \quad (1)$$

This share indicates how much industry  $i, j$  depends on a particular supplier. To measure foreign upstream exposure, I weight these supplier shares with the climate policy stringency of the supplier country and aggregate over all  $k \neq i$ :

$$Foreign_{ij}^{Up} = \sum_{k \neq i} CP_k \times \sum_\ell \frac{II_{ij}^{k\ell}}{\sum_k \sum_\ell II_{ij}^{k\ell}}. \quad (2)$$

Analogously, downstream exposure is measured by the extent to which industry  $i, j$  sells intermediates to foreign customers. The importance of a downstream industry  $k, \ell$  is given by the share of inputs it sources from  $i, j$  relative to its total intermediates:

$$Foreign_{ij}^{Down} = \sum_{k \neq i} CP_k \times \sum_\ell \frac{II_{k\ell}^{ij}}{\sum_i \sum_j II_{k\ell}^{ij}}. \quad (3)$$

These measures capture how tightly an industry is connected to foreign climate policies through its suppliers and customers, thereby tracing exposure along both upstream and downstream channels and providing the foundation for the empirical analysis. The

underlying climate policy indicators are available only at the national level, which means that in equations 2 and 3 the policy term  $CP_k$  varies across countries but not across industries within a country. To introduce sectoral heterogeneity, I follow Albrizio et al. (2017) and Dechezleprêtre and Kruse (2022) by interacting  $CP_k$  with within-country carbon intensity shares, so that more carbon-intensive industries receive greater effective weight. This refinement allows exposure to vary at the  $k, \ell$  level, reflecting the fact that national policies typically target high-emission sectors more strongly than low-emission ones.

Because the policy indicators are national, an additional complication arises for domestic linkages: a change in  $CP_i$  mechanically shifts both a focal industry and its domestic suppliers at the same time, making it difficult to disentangle direct effects from propagation through the network. Dechezleprêtre and Kruse (2022), for instance, construct supply chain weights without distinguishing between domestic and foreign connections, which means that their exposure measure inevitably blends the two. By focusing instead on foreign linkages, where the policy shock originates outside the domestic regulatory process, I can exploit the sectoral heterogeneity introduced above while avoiding this contamination. Foreign policies may still move together across countries, but I address this in the empirical analysis with a granular instrumental variable that isolates nationally idiosyncratic components of policy changes.

To ensure that exposure is not mechanically shaped by policy-induced changes in production structures, I fix the production network at its 1995 configuration and likewise use carbon intensities from the beginning of the sample. This design keeps both linkages and emission intensities predetermined, such that the only source of time variation is climate policy itself. In robustness checks, I relax these assumptions and show that the results are not sensitive to using time-varying networks. Another potential concern with input-share based measures is that they may double count contributions when intermediates cross borders multiple times. As a robustness check, I therefore also construct exposure measures using value-added linkages based on a Leontief (1986) decomposition, which attribute foreign contributions to their ultimate origin. These results are presented in

the robustness section.

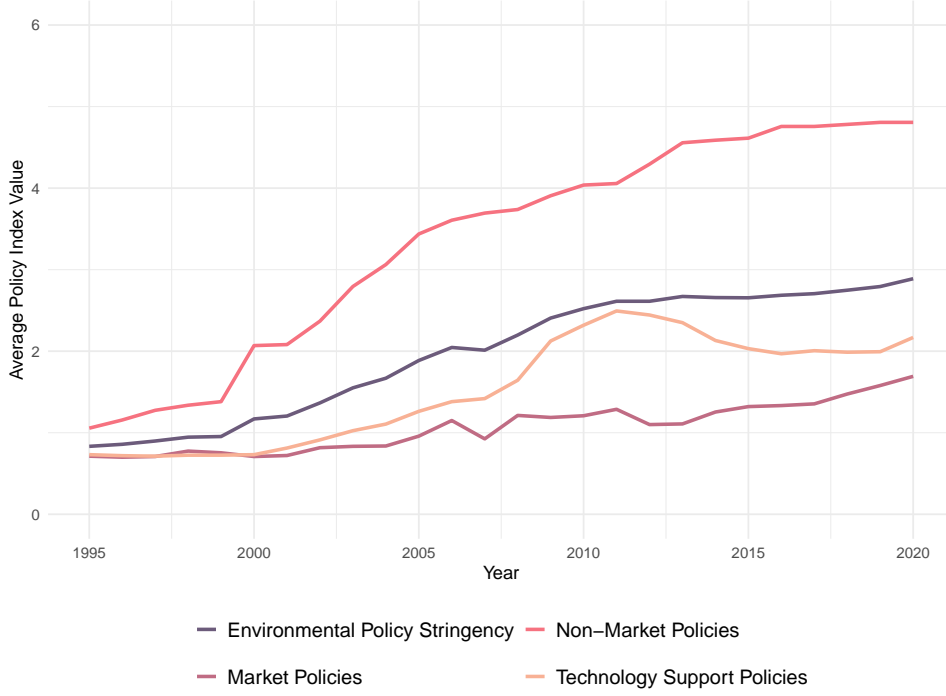
## 4 Data

The measure of climate policy stringency builds on the OECD’s Environmental Policy Stringency (EPS) Index, which is available and comparable across 40 countries between 1990 and 2020. The EPS is widely used in the literature on climate policy and productivity growth (Feng et al. 2021, Albrizio et al. 2017, Wang et al. 2019, OECD 2021, Martínez-Zarzoso et al. 2019, Benatti et al. 2024, Dechezleprêtre and Kruse 2022, among others). It provides a country-level indicator of regulatory efforts to mitigate climate change and is constructed from three equally weighted subcomponents: market-based instruments, non-market regulations, and technology support measures. Market-based policies cover the stringency of taxes on carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), and diesel emissions, as well as the existence and scope of trading schemes for CO<sub>2</sub> and renewable energy certificates. Non-market policies capture emission limit values for CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, and diesel sulfur content. The technology support component reflects policy support for solar and wind deployment together with public expenditures on energy-sector R&D. To introduce sectoral variation, I interact the country-level EPS with relative carbon intensity measures within each country. Carbon intensity is calculated as production-based greenhouse gas emissions relative to value added, using emissions data from the OECD Greenhouse Gas Footprints (GHGFP) dataset and value added from the OECD ICIO tables. I restrict the measure to production-based emissions.

At the country level, Figure 1 shows the evolution of the EPS and its subcomponents. The overall index follows an upward trend, but the trajectories of individual components differ. Because each subcomponent is scaled within its own policy domain, the figures reflect relative changes over time rather than absolute comparability across domains. Non market regulations tighten steadily, whereas technology support peaks around 2011 before declining. Appendix Figure A1 further disaggregates the EPS by country and indicates that all countries in the sample experience increases in policy stringency on

average, though the timing and intensity of these changes vary substantially.

**Figure 1: Environmental Policy Stringency Index**

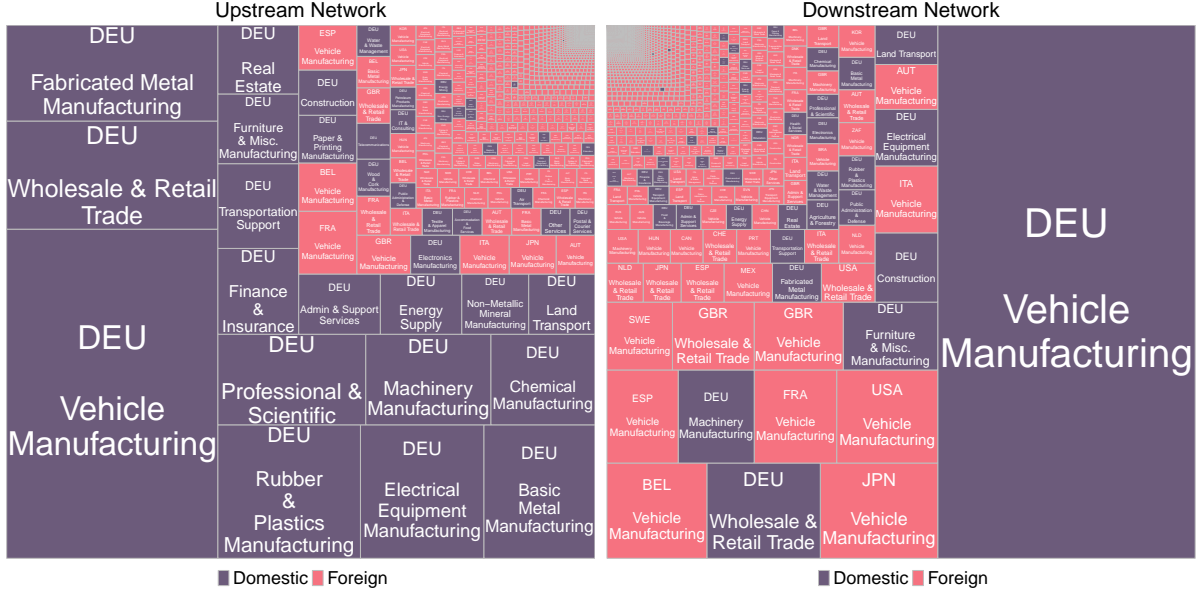


The figure shows the average Environmental Policy Stringency (EPS) Index and its three components over time for the full sample; each component contributes equally to the overall index.

To construct supply chain weights for foreign upstream and downstream industries, I use the OECD Inter-Country Input-Output (ICIO) tables, which cover 76 countries and 44 industries from 1995 to 2020. The sample is restricted to the 40 countries with available EPS data. I exclude the industry class "Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use" as it does not provide intermediate inputs to other industries. Figure 2 shows the predetermined production network of the German vehicle manufacturing industry in 1995. The left panel displays upstream linkages, that is, industries supplying intermediate inputs to German vehicle manufacturing. The right panel shows downstream linkages, where the industry provides intermediates used as inputs by other industries. The size of each square reflects the relative importance of a supplier or customer within the total set of linkages, as defined in equation 1 for suppliers. The figure indicates the high degree of international integration of this industry already in 1995: about one third of the interme-

diates used by German vehicle manufacturing were sourced from abroad, while roughly one half of its output was absorbed as intermediates by foreign industries.

**Figure 2:** Upstream and Downstream Supply Chain Linkages of German Vehicle Manufacturing



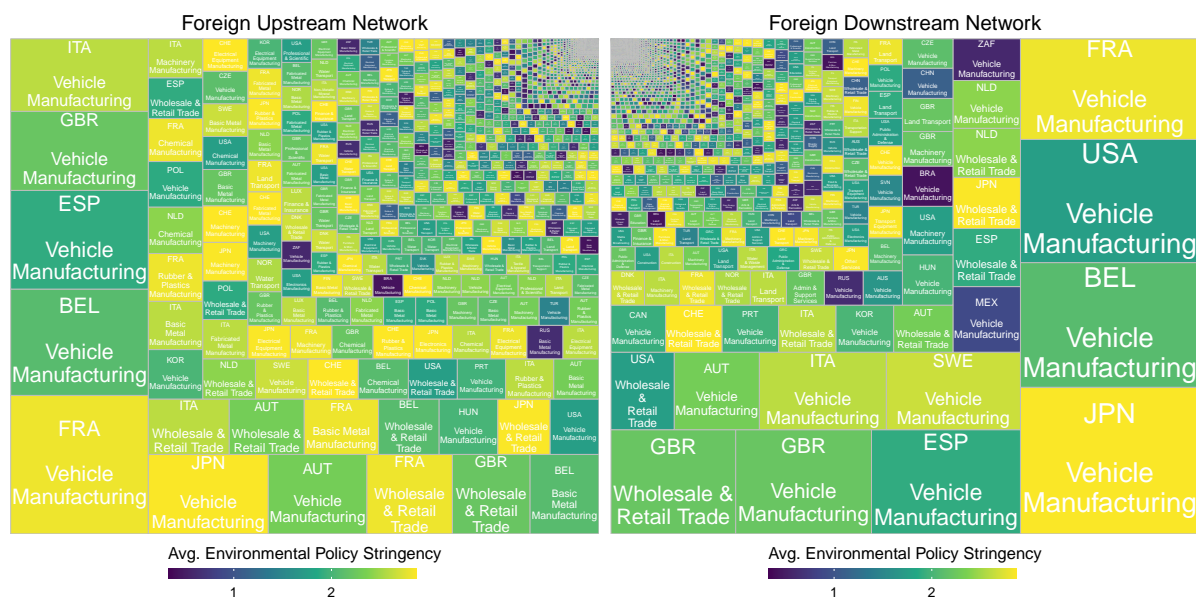
Notes: The size of each square reflects the relative importance of industries in the network: upstream suppliers in the left panel (inputs provided) and downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure.

Manufacturing industries are generally more internationally integrated than other sectors, but the degree of integration varies substantially. The US fabricated metal industry, for example, has a relatively small foreign network and an asymmetric pattern: it sources a larger share of inputs from abroad than it sells to foreign customers, resulting in a limited downstream foreign network (Appendix Figure A2). By contrast, Japanese electronics manufacturing, including semiconductors, relies mainly on domestic inputs but directs a large share of output to foreign industries (Appendix Figure A3).

These descriptive patterns highlight that foreign production networks provide the channels through which climate policy abroad can reach domestic industries. Given a fixed network structure, differences in linkages imply differences in the extent to which national productivity is exposed to foreign regulatory changes. Figure 3 displays the foreign production network of German vehicle manufacturing, restricted to cross-border linkages, with shading indicating the average climate policy stringency of suppliers and customers. Trading partners span a wide range of policy regimes, and comparisons across

industries, such as German vehicles, US fabricated metals, and Japanese electronics (Appendix Figures A4 and A5), reveal systematic differences in exposure to foreign climate policies. Foreign link weights are concentrated, with a small set of industries accounting for most inputs and outputs. This concentration generates the granular shocks that form the basis of the empirical strategy, developed formally in the next section.

**Figure 3:** Exposure to Foreign Climate Policy Exposure via Supply Chain Linkages for German Vehicle Manufacturing Industry



Notes: The size of each square reflects the relative importance of industries in the foreign network: foreign upstream suppliers in the left panel (inputs provided) and foreign downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure. Exposure is shown using the country-level Environmental Policy Stringency (EPS) Index without carbon-intensity weighting; shading reflects the average stringency of partner countries' policies.

Productivity is measured as value added in chain linked volumes relative to employed workers, using data from the OECD Structural Analysis (STAN) database. To align classifications across the ICIO and STAN datasets, I aggregate the paper products and printing industry, listed as C17\_18 in ICIO but split into C17 and C18 in STAN. All other industries match without further adjustment.<sup>1</sup> In addition to productivity, value added, and employment, which form the baseline outcomes, I also report results for car-

<sup>1</sup>In robustness checks, I consider alternative productivity measures. First, I use value added per hour worked instead of per employee. Second, I measure value added from the ICIO tables rather than from STAN. While the ICIO tables ensure consistency with input-output accounting, STAN is designed to provide the closest match to national accounts, making it the preferred baseline. Finally, I test specifications with nominal instead of real (chain-linked volume) value added to assess the role of price effects. Results are robust across all alternatives.



bon emissions, carbon intensity (emissions per unit of value added), and capital intensity. Emissions and carbon intensity are taken from the OECD Greenhouse Gas Footprints (GHGFP) dataset, restricted to production-based emissions, while capital intensity (capital stock relative to employment) is sourced from STAN. These supplementary outcomes, reported in the Appendix, provide complementary evidence on environmental performance and input reallocation in response to foreign climate policies.

## 5 Empirical Analysis

### 5.1 Granular Instrumental Variable

In the spirit of Gabaix and Koijen (2021, 2024), I construct a granular instrumental variable (GIV) by extracting idiosyncratic shocks from foreign upstream and downstream industries. As a starting point, consider a simplified setting in which one estimates the effect of exposure to foreign climate policies via upstream linkages,  $ForeignUp_{ij,t}$ , on industry productivity:

$$\Delta \ln Y_{ij,t} = \alpha \Delta \ln ForeignUp_{ij,t} + \epsilon_{ij,t}. \quad (4)$$

As defined in equation 2, upstream exposure to foreign climate policies,  $ForeignUp_{ij,t}$ , is the weighted average of foreign countries' policy stringency, with weights given by the share of inputs sourced from each foreign upstream industry. Exposure to a specific foreign upstream industry  $k, \ell$  can be written as

$$ForeignUp_{ij,t}^{k \neq i, \ell} = \frac{CP_{k \neq i, t} \cdot II_{ij,t}^{k \neq i, \ell}}{\sum_k \sum_\ell II_{ij,t}^{k \ell}}. \quad (5)$$

The aggregate change in exposure is then a weighted sum of disaggregated changes:

$$\Delta \ln ForeignUp_{ij,t} = \sum_{k \neq i} \sum_{\ell} w_{ij,t-1}^{k \neq i, \ell} \Delta \ln ForeignUp_{ij,t}^{k \neq i, \ell}, \quad (6)$$

where  $w_{ij,t-1}^{k \neq i, \ell}$  is the lagged share of upstream industry  $k, \ell$  in total foreign upstream exposure. Each disaggregated change can be decomposed into a common component  $\eta_{ij,t}$  with uniform factor loading  $\lambda$  and an idiosyncratic component  $u_{ij,t}^{k \neq i, \ell}$ :

$$\Delta \ln ForeignUp_{ij,t}^{k \neq i, \ell} = \lambda \eta_{ij,t} + u_{ij,t}^{k \neq i, \ell}. \quad (7)$$

Here,  $u_{ij,t}^{k \neq i, \ell}$  denotes the idiosyncratic shock originating in foreign industry  $\ell$  in country  $k \neq i$  that propagates to domestic industry  $i, j$  via upstream linkages. In the simplified derivation, it is treated as orthogonal to the common component  $\eta_{ij,t}$  and the residual  $\epsilon_{ij,t}$ , to illustrate the intuition of the GIV construction.

The GIV is then defined as the difference between the size-weighted and equal-weighted averages of disaggregated shocks:

$$z_{ij,t} = \Delta \ln ForeignUp_{ij,t} - \overline{\Delta \ln ForeignUp_{ij,t}} \quad (8)$$

$$= \sum_{k \neq i} \sum_{\ell} \left( w_{ij,t-1}^{k \neq i, \ell} \Delta \ln ForeignUp_{ij,t}^{k \neq i, \ell} - \frac{1}{N} \Delta \ln ForeignUp_{ij,t}^{k \neq i, \ell} \right) \quad (9)$$

$$= \sum_{k \neq i} \sum_{\ell} \left( w_{ij,t-1}^{k \neq i, \ell} (\lambda \eta_{ij,t} + u_{ij,t}^{k \neq i, \ell}) - \frac{1}{N} (\lambda \eta_{ij,t} + u_{ij,t}^{k \neq i, \ell}) \right) \quad (10)$$

$$= \sum_{k \neq i} \sum_{\ell} u_{ij,t}^{k \neq i, \ell} \left( w_{ij,t-1}^{k \neq i, \ell} - \frac{1}{N} \right) \quad (11)$$

$$= \tilde{u}_{ij,t} - \bar{u}_{ij,t}, \quad (12)$$

where  $\tilde{u}_{ij,t}$  and  $\bar{u}_{ij,t}$  denote the size-weighted and equal-weighted averages of idiosyncratic shocks, respectively. This formulation shows that the instrument exploits heterogeneity in link weights across upstream industries. If exposures were evenly distributed, the instrument would collapse to zero and be uninformative. A key feature of this approach is that the common component  $\eta_{ij,t}$  is purged, so identification relies on the orthogonality between idiosyncratic upstream shocks and the aggregate error term. An analogous construction applies to downstream linkages.

To isolate idiosyncratic variation, I regress disaggregated exposure to foreign climate

policies on a set of fixed effects:

$$\Delta \ln ForeignUp_{ij,t}^{k \neq i, \ell} = \alpha_{ij,t} + \alpha_{j=\ell,t} + \alpha_{ij}^{k\ell} + u_{ij,t}^{k \neq i, \ell}. \quad (13)$$

The specification is designed to absorb several sources of endogeneity. The term  $\alpha_{ij,t}$  denotes domestic industry-year fixed effects. These capture domestic shocks such as macroeconomic conditions or regulatory reforms that may simultaneously influence all foreign linkages. They are also important for addressing simultaneity, since shocks to domestic productivity could otherwise feed back into the policy stance of major trading partners and create reverse causality.<sup>2</sup> The term  $\alpha_{j=\ell,t}$  captures same industry-year interactions, which absorb coordinated interventions targeting an industry across multiple countries in the same year, for example the alignment of automotive emission standards. Finally,  $\alpha_{ij}^{k\ell}$  denotes bilateral country industry pair effects, which control for time invariant structural features of trade relationships including geography, technological complementarities, or long standing supply arrangements.

The residuals  $u_{ij,t}^{k \neq i, \ell}$  from equation (13) represent uncoordinated changes in foreign climate policies transmitted to domestic industries through upstream linkages at the bilateral, disaggregated level. These form my measure of idiosyncratic shocks. Nonetheless, the residuals may still share subtle components not fully purged by the fixed effects, for instance when several countries adjust policies in response to a common but not formally coordinated shock such as a spike in global energy prices. Following Gabaix and Koijen (2021, 2024), I address this by applying principal component analysis to the set of residuals for each domestic country-industry across all its foreign upstream industries. The first three principal components are then included as additional controls in the 2SLS regressions. This procedure reduces the risk that remaining common shocks contaminate the instrument while preserving the granular, industry-specific variation needed for identification.

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<sup>2</sup>Another channel of simultaneity arises if domestic climate policies affect foreign policy choices (see, for example, Fields and Lindequist 2024). In this case, exposure to foreign policy shocks would be correlated with domestic policies themselves. Controlling directly for domestic policy does not fully solve this issue, since the domestic policy could still work indirectly by shaping the foreign policy environment.

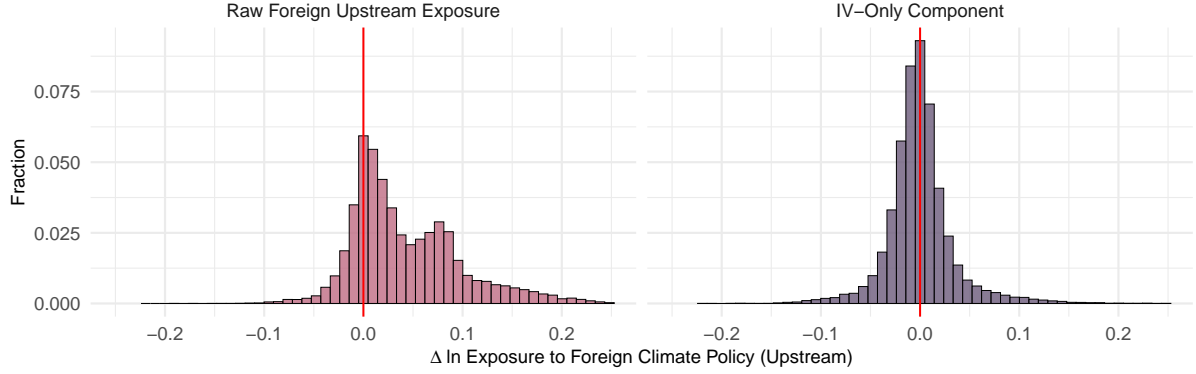
Finally, I aggregate to the country-industry level by computing the difference between the size-weighted and equal-weighted averages of the bilateral residuals  $u_{ij,t}^{k \neq i, \ell}$ . This aggregated variable constitutes the granular instrumental variable used in the estimation. The bilateral pre-step, combined with the PCA adjustment, ensures that the instrument is purged of broad policy movements and persistent link-level confounders, leaving only granular shocks that vary across individual foreign industries. I apply this procedure consistently across all climate policy variables, constructing instruments not only for the overall EPS but also separately for its subcomponents.

A potential concern is that many climate policies are coordinated across countries, leaving little independent variation once common shocks are taken into account. To assess this, Figure 4 illustrates the identifying variation in a Frisch-Waugh-Lovell framework. I partial out both upstream exposure and the instrument with respect to controls and principal components, regress the residualized upstream exposure on the residualized instrument, and plot the fitted values. The distribution of this fitted component retains substantial dispersion, showing that meaningful variation remains after controlling for common movements. This exercise speaks to instrument relevance: there is sufficient variation to identify the effect of foreign climate policy exposure. The instrumental variable is then crucial for ensuring that this variation is exogenous, since exposure may still be correlated with domestic shocks or broader policy dynamics.

## 5.2 Local Projections

In order to examine the dynamic relationship between productivity and exposure to foreign climate policies transmitted through production linkages, I employ the local projections method of Jordà (2005). This approach directly estimates impulse responses at each horizon, allowing for greater flexibility than a parametric VAR specification. To address the endogeneity of exposure measures, I combine local projections with the granular instrumental variable, following Jordà and Taylor (2016), Ramey and Zubairy (2018), and Jordà et al. (2022). For expositional clarity, I present the specification using upstream

**Figure 4:** Upstream Exposure to Foreign Climate Policies: Raw Series and Identifying Component



Notes: The left panel shows the distribution of raw change in upstream exposure to foreign climate policies. The right panel shows the fitted values from regressing residualized exposure on the residualized instrument, representing the identifying component net of controls. Both upstream exposure and the instrument are residualized with respect to the controls used in the second stage of the local projection IV framework: domestic climate policy, lagged productivity, and the first three principal components of the upstream measure. Values are truncated to the interval  $[-0.25, 0.25]$  for readability.

exposure:

$$y_{ij,t+h} - y_{ij,t} = \beta_0^h + \beta_1^h \Delta \ln \widehat{ForeignUp}_{ij,t+1} + \beta_2^h \Delta y_{ij,t} + \beta_3^h X_{ij,t} + \alpha_{ij}^h + \alpha_t^h + \varepsilon_{ij,t}^h,$$

where  $y$  denotes the outcome of interest (log productivity, log value added, log employment, log carbon emissions, log carbon intensity, or log capital intensity). The regressor  $\Delta \ln \widehat{ForeignUp}_{ij,t+1}$  is the instrumented change in foreign upstream exposure between  $t$  and  $t + 1$ . Hence, impulse responses are traced from  $t + 1$  onwards. The specification controls for one lag of the dependent variable,  $\Delta y_{ij,t}$ , as well as a vector  $X_{ij,t}$  that includes changes in domestic climate policy and the first three principal components from the relevant exposure network.<sup>3</sup> In the main specification, based on the average of upstream and downstream foreign exposures, I include the principal components of both networks separately. When estimating upstream or downstream effects in isolation, I include only the corresponding set of principal components. Country-industry fixed effects ( $\alpha_{ij}^h$ ) and time fixed effects ( $\alpha_t^h$ ) are also included.

<sup>3</sup>The results are qualitatively identical to including either less or more principal components.

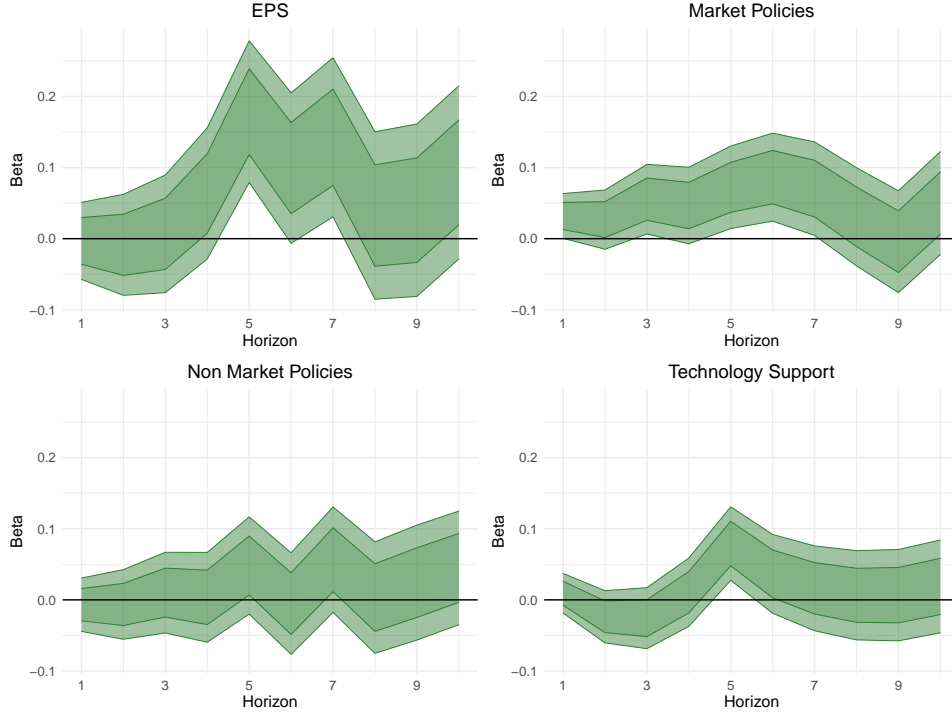
While upstream exposure is used here for illustration, the empirical analysis relies primarily on the average of upstream and downstream exposures. This composite measure provides a more comprehensive gauge of how international production networks transmit climate policy spillovers, and it forms the basis of the main results presented in the next section.

### 5.3 Baseline Results

Figure 5 presents the estimated impulse responses of productivity to a one percent increase in foreign climate policy exposure transmitted through production linkages. Results are reported for the overall exposure measure based on the Environmental Policy Stringency Index as well as for its three subcomponents, namely market based policies, non market regulations, and technology support policies. The shaded areas represent 90 and 68 percent confidence intervals, with standard errors clustered at the country-industry level. For the overall measure, productivity increases by about 0.1 to 0.2 percent at horizons five to seven years following the shock, indicating that the effects of foreign climate policies materialize only with a delay. When considering the subcomponents separately, exposure to market based policies and to technology support policies also leads to positive productivity responses at medium horizons, although the estimated magnitudes are smaller than for the aggregate measure. In contrast, exposure to non market regulations does not produce statistically significant productivity effects at any horizon. Overall, the evidence from the baseline specifications suggests that foreign climate policy exposure affects productivity primarily through medium horizon adjustments, with heterogeneous outcomes depending on the type of regulation.

To examine whether productivity responses reflect changes in labor input or in value added per worker, I estimate the effects of foreign climate policy exposure on real value added (Figure 6) and on employment (Figure 7). For the overall exposure measure based on the EPS index, employment declines while value added increases. By policy type, exposure to non market regulations is associated with decreases in both variables, whereas exposure to market based policies and to technology support policies is associated

**Figure 5:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity

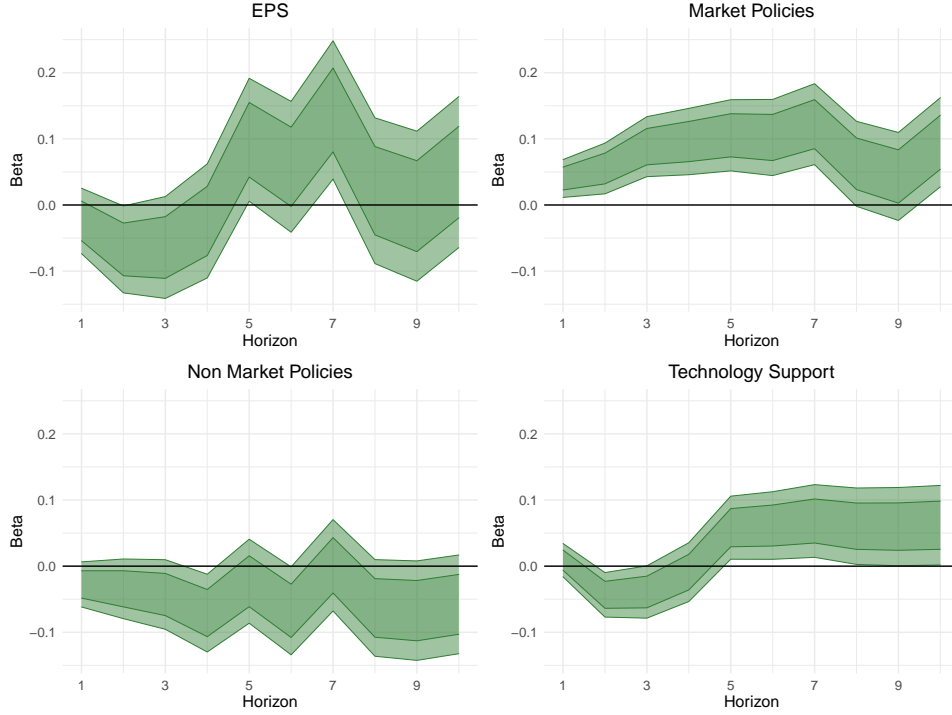


Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

with increases in both. These results indicate that the productivity improvements under market based and technology support policies are not driven by labor displacement, but by a more than proportional rise in value added relative to employment.

The baseline results are based on the average of upstream and downstream linkages, providing a measure of overall exposure to foreign climate policies through the production network. The responses may nevertheless differ depending on whether the policy shock originates from suppliers or from customers. For example, downstream regulation can create incentives for suppliers to adapt their products (Lin et al. 2024), whereas upstream regulation may pass through improvements or constraints that originate with input providers. Figure 8 shows the results when the channels are examined separately. For the overall EPS exposure, the positive medium horizon productivity effects are mainly due to upstream propagation, while downstream propagation is statistically significant only at one horizon. For the subcomponents, exposure through downstream linkages is not statistically significant at the 90 percent confidence level. In contrast, upstream

**Figure 6:** Dynamic Effects of Foreign Climate Policy Exposure on Value Added



Notes: The figure shows local projections of value added responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

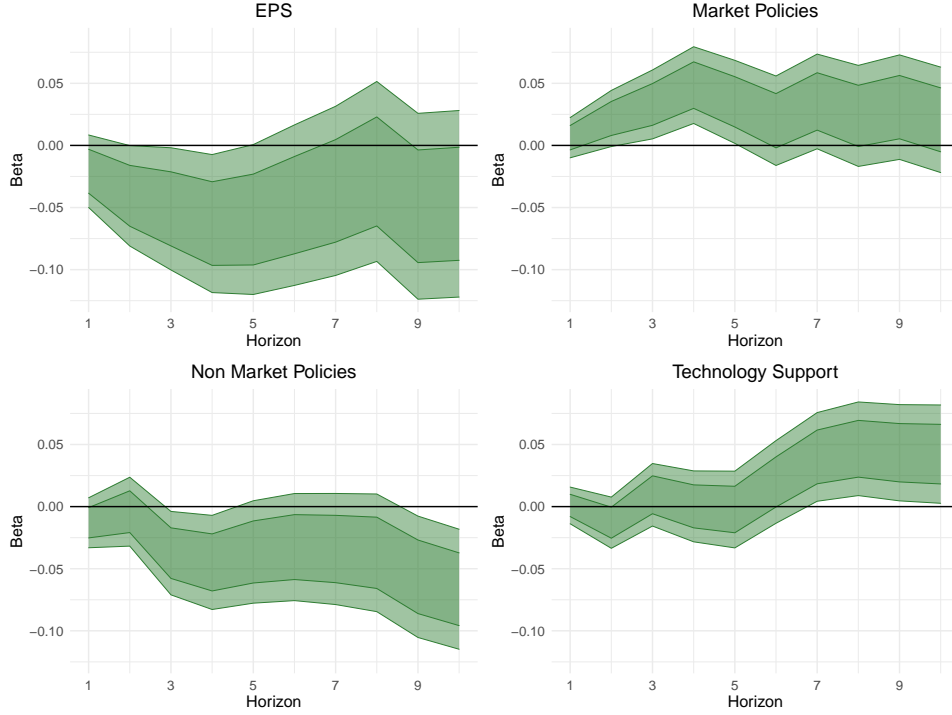
propagation generates positive and significant effects for both market based policies and technology support policies. Overall, these findings indicate that supplier linkages play a more important role in transmitting foreign climate policy shocks than customer linkages.

In addition to productivity, I also examine environmental outcomes that connect more directly to the climate policy debate. The results, reported in Appendix Figures A6 and A7, show that foreign policy exposure reduces both domestic emissions and carbon intensity, pointing to cleaner production without evidence of carbon leakage. These complementary findings suggest that the productivity gains documented above are accompanied by environmental improvements, reinforcing the view that international policy spillovers can support both competitiveness and mitigation objectives.<sup>4</sup> Turning to

<sup>4</sup>Empirical evidence on carbon leakage is highly mixed. Some studies document that stricter climate policies shift production and emissions abroad (Aichele and Felbermayr 2012, 2015, Hanna 2010, Tanaka et al. 2022, Ying et al. 2025, among others), while others find little or no evidence of leakage under existing schemes (Naegel and Zaklan 2019, Colmer et al. 2025, Dechezleprêtre et al. 2022, Eskander and Fankhauser 2023, among others). The reductions in emissions and carbon intensity observed here are inconsistent with a leakage mechanism, suggesting instead that foreign policies contribute to cleaner domestic production.



**Figure 7:** Dynamic Effects of Foreign Climate Policy Exposure on Employment

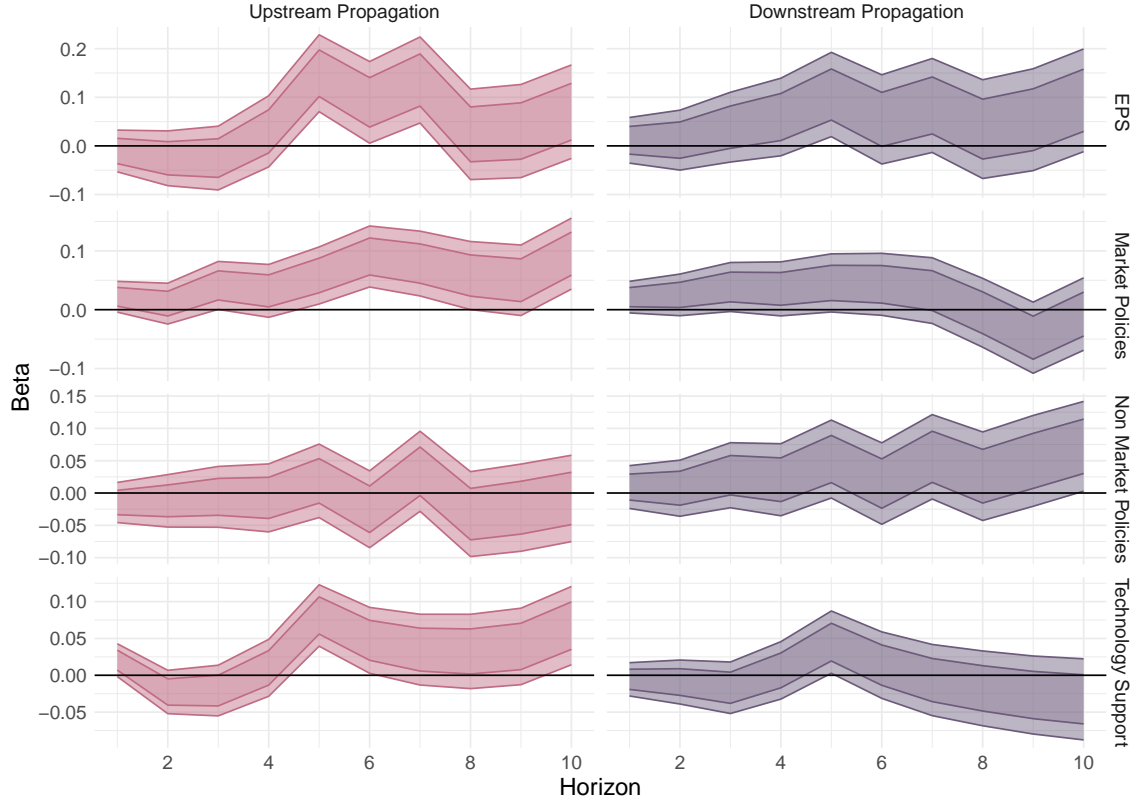


Notes: The figure shows local projections of employment responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

capital intensity (Appendix Figure A8), I find significant effects for the overall EPS and for non-market regulations, whereas exposure to market-based policies is associated with reductions in capital intensity. One interpretation may be that market-based instruments, by raising the relative price of carbon-intensive inputs, induce substitution toward less capital-intensive production methods.

In sum, the baseline results show that foreign climate policy exposure transmitted through production networks raises domestic productivity, but the effects unfold only gradually, becoming statistically significant at medium horizons. The patterns in value added and employment suggest that the productivity gains are more likely linked to increases in output per worker than to simple labor shedding. They are further accompanied by reductions in emissions and carbon intensity. Overall, the evidence points to a gradual process of adjustment in which foreign climate policies ultimately contribute to both higher productivity and cleaner production.

**Figure 8:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity by Supply Chain Direction



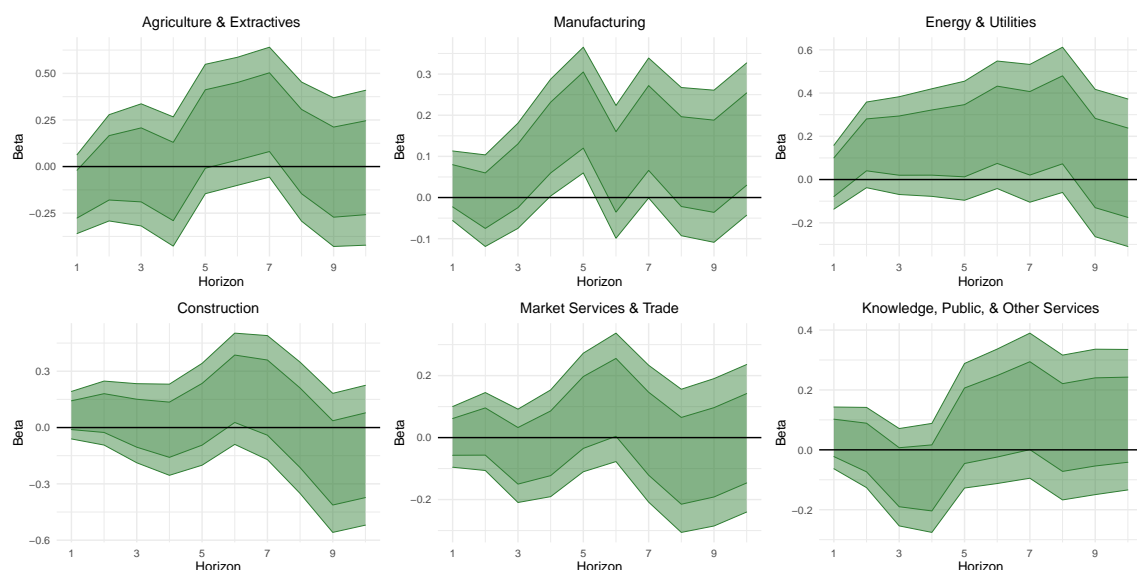
Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies. The left panel reports upstream propagation (via foreign suppliers), and the right panel downstream propagation (via foreign customers). Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

## 5.4 Heterogeneous Effects

To examine heterogeneity across industries, I group the 44 industries into six broad sectors: agriculture and extractives, manufacturing, energy and utilities, construction, market services and trade, and knowledge, public, and other services (see Appendix Table A2 for details on classification and aggregation). Figure 9 shows the estimated impulse responses for the overall EPS-based exposure measure. Among these sectors, manufacturing is the only one showing statistically significant productivity gains, consistent with its central role in global production networks and the fact that it accounts for 17 of the 44 industries in the sample. A closer look within manufacturing provides a more differentiated picture. Figure 10 reports the results by individual manufacturing industries and shows that positive productivity responses are particularly evident for electronics,

fabricated metals, food and beverages, machinery, and non-metallic minerals.

**Figure 9:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity by Broad Sector

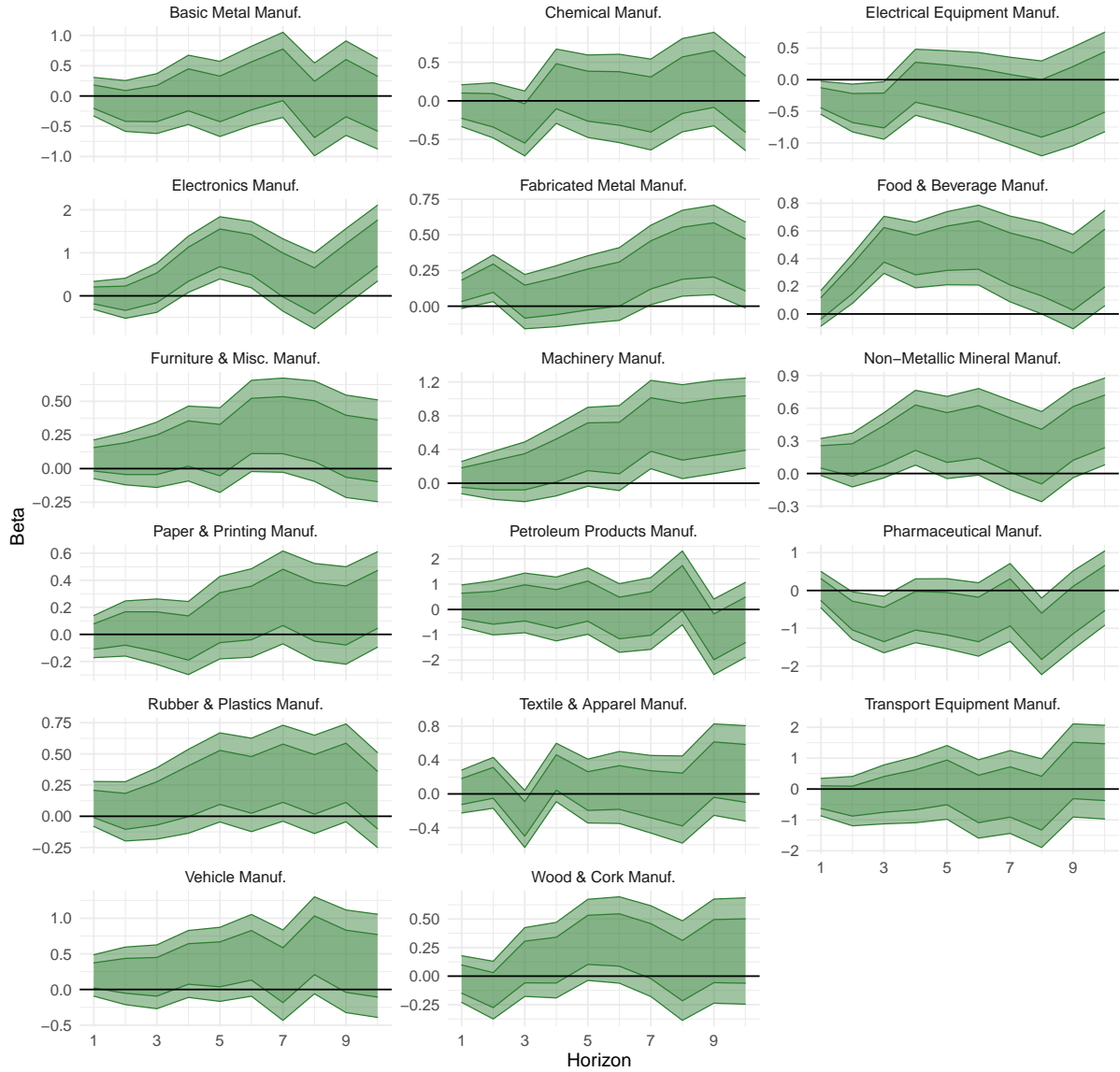


Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

Taken together, the findings underscore the central role of manufacturing and motivate a broader examination of heterogeneity across additional industry dimensions. Four characteristics are considered: global value chain participation, pollution intensity, domestic policy environment, and network position. These dimensions are chosen because they capture channels along which the effects of foreign climate policy exposure are likely to vary. Industries more integrated into global value chains may be more directly exposed to foreign shocks. Pollution intensity distinguishes between brown and green sectors, where the former may have greater scope to realize gains from stricter policies. The domestic policy environment indicates how foreign exposure interacts with national regulation, while network position reflects an industry's distance from final demand and the way shocks propagate through supply chains.

Global value chain participation is measured as the average of the share of foreign intermediate inputs used in production (upstream linkages) and the share of output supplied as intermediate inputs to foreign industries (downstream linkages). Pollution intensity is

**Figure 10:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity within Manufacturing Industries

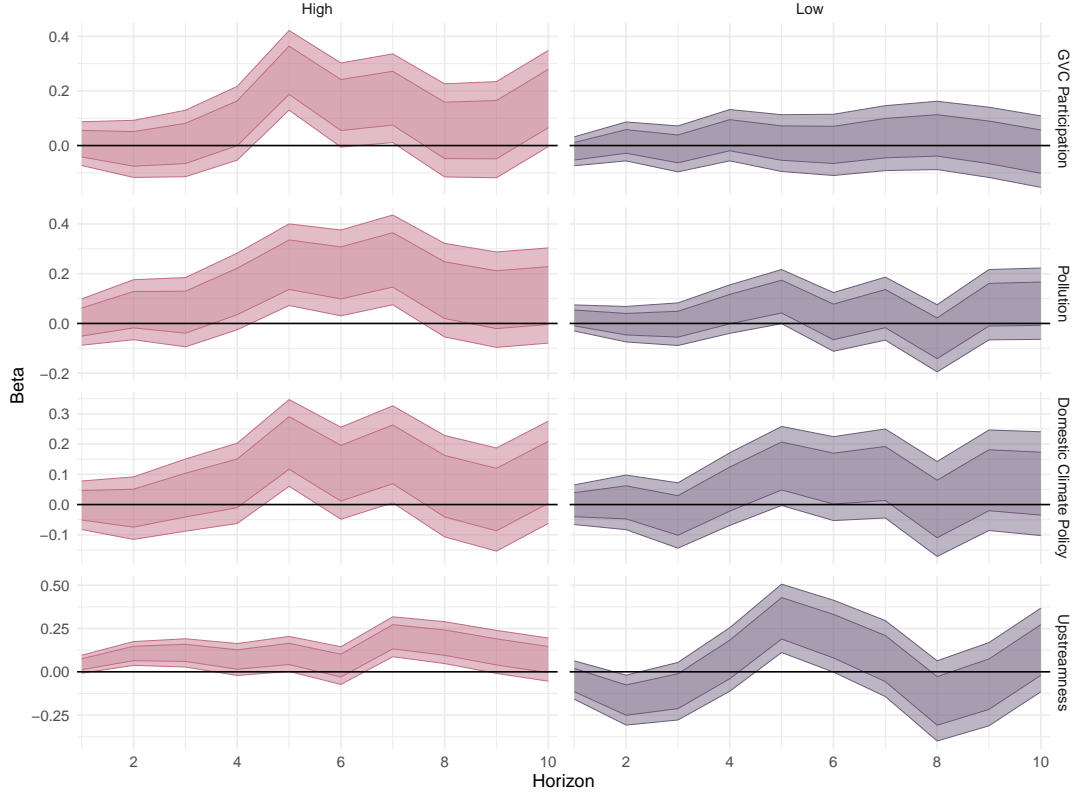


Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

captured by industry-level carbon emissions per unit of output. Domestic climate policy exposure is defined as national environmental policy stringency interacted with industry-level carbon intensity. Finally, upstreamness is calculated using the index of Antràs et al. (2012), which measures the distance of an industry's output from final demand. For each characteristic, industries are split into above- and below-median groups based on their average values over the sample period, and separate local projections are estimated for

each (Figure 11).

**Figure 11:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity by Industry Characteristics



Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Industries are split into above- and below-median groups along four dimensions: global value chain participation, pollution intensity, domestic policy exposure, and upstreamness. Shaded areas denote 90 percent and 68 percent confidence bands, with standard errors clustered at the country-industry level.

The results show that productivity effects are generally insignificant for the below-median groups. By contrast, positive medium-horizon effects emerge consistently for the above-median groups across global value chain integration, pollution intensity, and domestic policy exposure. For upstreamness, the pattern is more mixed, but the effects appear more persistent in industries located further from final demand. Taken together, these results suggest that productivity gains concentrate in industries that are more internationally integrated, more pollution intensive, more upstream in the production network, and subject to stricter domestic policies. These are precisely the settings where firms face both stronger pressure and greater scope to adjust. While the heterogeneity analysis does not pin down the exact channels, the pattern is consistent with two mech-

anisms highlighted in the literature: the development of new green technologies through innovation and the uptake or diffusion of cleaner inputs through adoption.

## 5.5 Mechanisms

### 5.5.1 Green Innovation

First, I examine whether the productivity effects of foreign climate policy exposure operate through a green innovation channel. The Porter hypothesis (Porter 1991, Porter and Linde 1995) has been the subject of extensive empirical work. Studies such as Jaffe and Palmer (1997), Ambec and Lanoie (2008), Dechezleprêtre and Sato (2017), and more recently Zhang et al. (2024), all find that environmental regulation tends to stimulate green innovation. However, the evidence on whether such innovation translates into productivity gains is far less clear. Research further shows that regulation can spur innovation not only within regulated firms but also along domestic supply chains, either theoretically (Greaker 2006, Heyes and Kapur 2011) or empirically (Lin et al. 2024, Franco and Marin 2017). Whether similar spillovers arise across borders through international production networks is much less understood. Building on this gap, I test whether foreign climate policies transmitted through global supply chains trigger green innovation responses that support productivity growth.<sup>5</sup>

To measure green innovation, I use patent data from the PATSTAT database. Green patents are identified using the Y02 category of the International Patent Classification (IPC), which covers technologies for the mitigation and adaptation of climate change. I collect all patents with a Y02 tag at the level of the filing authority, yielding about 2.7 million unique green patents over the sample period. To allocate patents to industries, I use the concordance tables of Mun et al. (2019), which map IPC codes to ISIC Rev. 4 industries.<sup>6</sup> Because patents can be linked to multiple IPC codes, they may map to more

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<sup>5</sup>More broadly, research shows that international trade can stimulate innovation through competition and knowledge diffusion. For example, Aw et al. (2011) document that firms entering export markets increase R&D spending, while Bas and Strauss-Kahn (2015) and Zhong (2023) show that imports of higher-quality or more diverse inputs foster domestic innovation. These insights suggest that foreign climate policies could amplify such dynamics along global supply chains.

<sup>6</sup>Patents are predominantly associated with manufacturing, with only a small share assigned to service industries such as finance, R&D, and business services (ISIC 65, 66, 72, 74, and 78).

than one industry. When all codes fall within a single industry, the patent is counted once; when they span multiple industries, each relevant industry receives one count.<sup>7</sup>

I estimate the dynamic effects of foreign climate policy exposure on green innovation by regressing changes in the number of climate change-mitigating patents, as well as their share in total patents, on the exposure measures within the LP-IV framework. Panel (a) of Figure 12 presents the impulse responses. The results show no short-run increase in green patenting, but both the level and the intensity of green patents rise significantly at longer horizons. When using the aggregate EPS index, there is little evidence of short-run effects and even a temporary decline around the five-year horizon. This aggregate picture, however, conceals important differences across policy types. Appendix Figure A10 reveals that exposure to foreign market-based policies and technology support policies significantly increases domestic green patenting, whereas exposure to non-market regulations reduces it. These findings are consistent with Dechezleprêtre and Kruse (2022) in showing no short-run effect of the aggregate EPS index on green patents. My analysis, however, goes further by tracing dynamics over longer horizons and by distinguishing between policy types. Once this heterogeneity is taken into account, market-based instruments and technology support emerge as drivers of green patenting, while non-market regulations have the opposite effect.

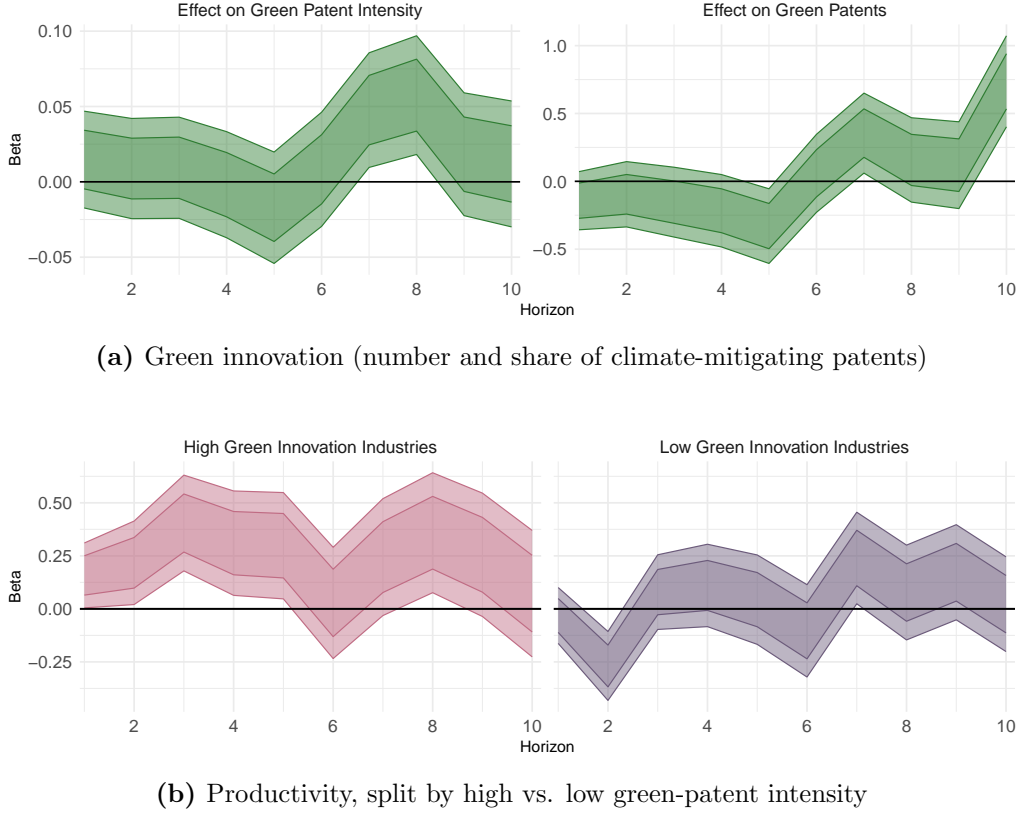
To assess whether these innovation responses translate into productivity gains, I split industries into high and low groups based on their green patent intensity. Panel (b) of Figure 12 shows that significant productivity increases following foreign climate policy exposure are concentrated in the high innovation group, while no such effects emerge for the low innovation group. The timing of the responses is not perfectly aligned, since patent filings are typically observed with a lag and productivity can also adjust through other channels. Rather than a contradiction, this pattern suggests that green innovation complements other mechanisms of adjustment, with industries that are more innovative ultimately better able to turn foreign regulatory pressure into productivity improvements.

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<sup>7</sup>Figure A9 plots the evolution of green patents before and after industry matching. While the matching procedure mechanically increases the number of observations, the time trend is unaffected, so this adjustment does not alter the interpretation of results.

Although alternative channels remain possible, the evidence is consistent with innovation playing an important role in shaping the productivity effects of foreign climate policies.

**Figure 12:** Dynamic Effects of Foreign Climate Policy Exposure on Green Innovation and Productivity



Notes: The panels plot local projections of responses to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Panel (a) reports responses of the level and share of green patents; panel (b) reports productivity responses estimated separately for industries above and below the median green-patent intensity. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

To further probe the mechanism, I distinguish between upstream and downstream exposure and estimate their effects on green patenting by policy type. The incentives for innovation differ across these channels: when customers face tighter regulation, suppliers may innovate to meet cleaner demand, as shown by Lin et al. (2024) for China, whereas when suppliers are regulated, downstream firms may respond defensively by investing in their own R&D to reduce dependence on licensed abatement technologies (Heyes and Kapur 2011). Other spillovers may also arise through technology diffusion or the wider availability of cleaner inputs. Appendix Figure A11 shows that the effects on green



patenting are comparable for upstream and downstream exposure, suggesting that both demand driven and supply driven channels contribute to the observed responses. This highlights innovation as a central mechanism behind the productivity effects, but it also raises the question of whether firms adjust more directly by changing their input mix, a complementary channel that I turn to in the next section.

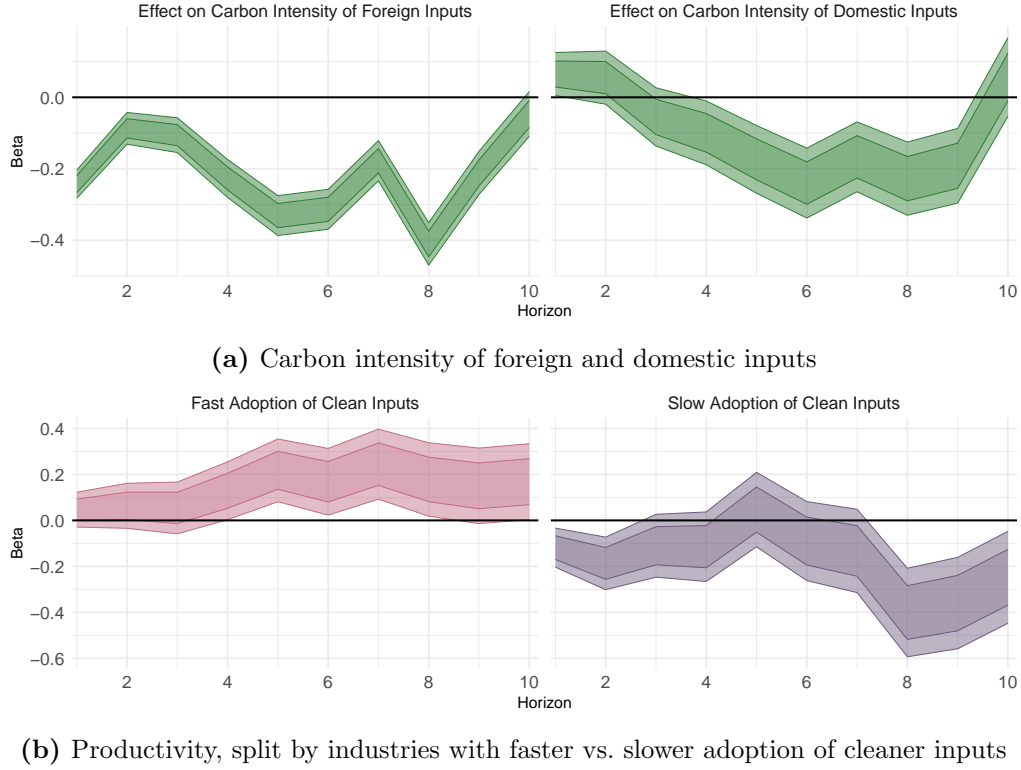
### 5.5.2 Adoption of Cleaner Inputs

While green innovation provides one plausible channel, productivity gains from foreign climate policy exposure may also arise through the adoption of existing technologies. To capture this mechanism, I proxy adoption by tracking the carbon intensity of intermediate inputs, which reflects the extent to which firms substitute toward cleaner production methods available in supply chains. Evidence from diverse settings supports the idea that adoption and diffusion of cleaner technologies can enhance productivity. For example, Adhvaryu et al. (2020) show that introducing energy-efficient lighting in Indian garment factories increased productivity while lowering energy costs, while Filippini et al. (2020) document that a national efficiency program in the Chinese steel industry raised total factor productivity by facilitating the uptake of underutilized technologies. At the macro level, Mercure et al. (2025) find that low-carbon transitions in the UK energy and transport sectors generated productivity gains through learning-by-doing, diffusion, and structural change.

To examine this channel in the international context, I construct a measure of the carbon intensity of intermediate inputs by interacting predetermined supplier shares with the supplying industry's carbon intensity. Aggregating over all foreign suppliers yields the carbon intensity of foreign inputs, while aggregation over domestic suppliers yields the carbon intensity of domestic inputs. Panel (a) of Figure 13 shows that foreign climate policy exposure reduces the carbon intensity of both foreign and domestic inputs, with a considerably stronger effect on the foreign component. This suggests that stricter regulation abroad induces cleaner inputs in supplier industries, which are subsequently adopted by domestic producers. At the same time, the effect on domestic inputs is not

unexpected, as foreign policies may diffuse through global supply chains or accelerate the domestic uptake of cleaner technologies.

**Figure 13:** Dynamic Effects of Foreign Climate Policy Exposure on Input Carbon Intensity and Productivity



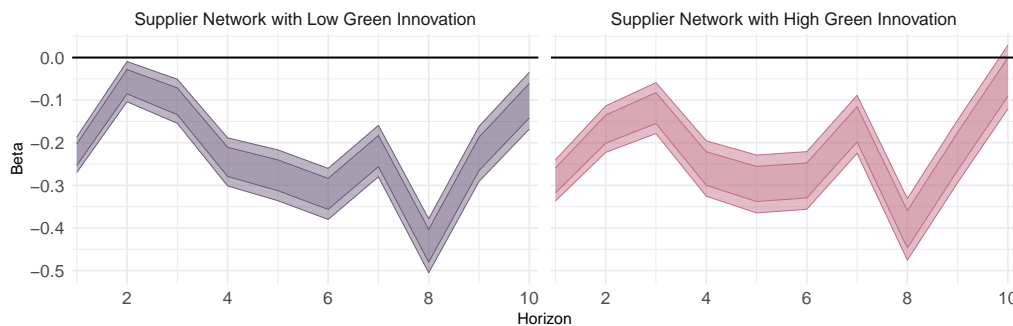
Notes: The panels plot local projections of responses to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Panel (a) shows the carbon intensity of foreign and domestic inputs; panel (b) shows productivity responses for industries classified into faster- and slower-adopting groups, based on historical reductions in foreign input carbon intensity. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

To assess whether the adoption of cleaner inputs conditions the productivity effects of foreign climate policy exposure, I group industries by their historical adoption performance, measured by the growth rate of reductions in foreign input carbon intensity over the sample period. Panel (b) of Figure 13 shows that productivity gains are concentrated in industries with a record of faster adoption, whereas industries with slower adoption even exhibit negative effects. This pattern suggests that the productivity channel operates through the ability of industries to integrate cleaner inputs into production processes.

A potential concern is that reductions in the carbon intensity of imported inputs

merely reflect the innovation capacity of foreign suppliers, rather than adoption decisions by domestic firms. To probe this, I construct a measure of exposure to supplier-side innovation by interacting predetermined foreign supplier shares with the number of green patents filed in the supplying industries and aggregating across suppliers. Figure 14 shows that the reduction in the carbon intensity of foreign inputs is nearly identical for industries more and less exposed to innovative suppliers. This pattern suggests that the effect of foreign climate policies on adoption is not simply a byproduct of upstream innovation capacity, but instead reflects a distinct adjustment by domestic firms that substitute toward cleaner inputs when their foreign partners face stricter regulation.<sup>8</sup>

**Figure 14:** Dynamic Effects of Foreign Climate Policy Exposure on the Carbon Intensity of Foreign Inputs by Supplier Innovation



Notes: The figure shows local projections of the carbon intensity of foreign inputs in response to a one percent increase in exposure to foreign climate policies, based on the overall EPS index and averaged across upstream and downstream linkages. Industries are split into above- and below-median groups according to their exposure to innovative suppliers, measured by foreign supplier shares weighted with green patenting activity. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

The mechanism analysis aligns with the heterogeneity patterns documented earlier. Productivity gains from foreign climate policy exposure emerge primarily in pollution-intensive industries and in those operating under stricter domestic regulation, that is, in settings where both the scope for adjustment and the incentives to adapt are greatest. In such contexts, foreign policies can foster green innovation and accelerate the adoption of cleaner inputs, while in cleaner sectors or under weaker domestic policy environments these channels are less likely to operate. Taken together, the evidence indicates that

<sup>8</sup>Input prices are not observed in this analysis, but it is plausible that part of the response reflects price dynamics. For instance, technology support policies may expand the supply of low-carbon intermediates and lower their relative cost, making cleaner inputs more widely available along supply chains and encouraging their diffusion.

productivity effects do not arise directly but are mediated by the capacity of industries to innovate and adapt. The following section examines whether these findings remain robust under alternative specifications.

## 5.6 Robustness

A first robustness check uses value-added linkages instead of intermediate input shares to construct climate policy exposure. One motivation for this alternative approach is that input-share based weights may double count contributions when intermediate goods cross borders multiple times. Value-added linkages, by contrast, are based on a Leontief (1986) decomposition that traces the ultimate origin of value added embodied in production, thereby emphasizing different aspects of global production linkages discussed in the global value chain literature (see, for example, Timmer et al. 2015, 2016). For the transmission of climate policies, this distinction may matter because value-added linkages capture the foreign value embodied in inputs from earlier production stages, including upstream energy- and resource-intensive sectors where regulation has its primary effects, whereas the baseline measure emphasizes direct intermediate linkages.

Formally, total value added in the production of a final good can be decomposed using Leontief’s method as

$$VA = \mathbf{F}(\mathbf{I} - \mathbf{B})^{-1}\mathbf{D}, \quad (14)$$

where  $\mathbf{B}$  denotes the matrix of technical coefficients,  $\mathbf{F}$  is a diagonal matrix with the ratio of value added to gross output, and  $\mathbf{D}$  is the vector of final demand. This Leontief decomposition attributes the value-added contributions of all country-industry pairs to the final output of a given industry. Based on this framework, I construct exposure by interacting foreign climate policy stringency with the bilateral value-added shares of foreign suppliers and aggregating over all foreign industries.<sup>9</sup> As in the baseline, I then take the average of upstream and downstream exposure to obtain the overall measure for exposure to foreign climate policies. The estimated impulse responses for the overall

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<sup>9</sup>Analogously, I construct a downstream value-added measure that captures the domestic value added embodied in foreign production. This is obtained by aggregating over all downstream foreign linkages after weighting them with the climate policy stringency of the respective foreign industries.

EPS index and its three subcomponents are shown in Figure 15. The results indicate that the effects are more pronounced than in the baseline specification, with non market based policies now also displaying a positive impact. Taken together, the productivity gains remain robust across both weighting schemes.

**Figure 15:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity using Value-Added Linkages

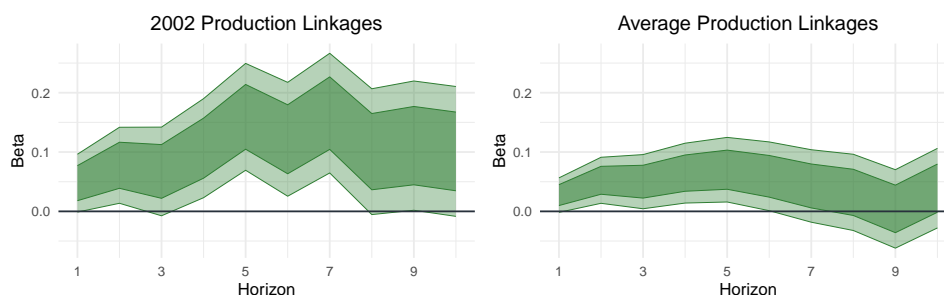


Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, constructed using value-added linkages rather than intermediate input shares. Exposure is averaged across upstream and downstream linkages and reported for the overall EPS index and its three subcomponents. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

A second robustness check considers alternative definitions of the production network. In the baseline, linkages are fixed at their 1995 configuration to avoid endogeneity concerns. As an alternative, I use the 2002 network, which reflects the substantial reorganization of global trade following China's accession to the WTO in December 2001. I also construct an average network over the entire sample period. The latter captures a more representative picture of long-run trade patterns, though it potentially allows production structures to adapt to policy changes themselves, introducing a trade-off between representativeness and exogeneity. Figure 16 shows that the results remain robust across these alternatives. In particular, the positive productivity effects persist when using averaged linkages, suggesting that even if trade relationships occasionally adapt

to regulation, as documented by Benincasa et al. (2024) for California’s cap-and-trade program, such adjustments do not occur at a scale that overturns the main findings. This is consistent with a broader view in the production network literature that cross-border supply relationships are relatively sticky and harder to substitute than domestic ones, which makes them less likely to adjust rapidly in response to policy shocks (see, e.g., Boehm et al. 2019, Gopinath and Neiman 2014, Carvalho et al. 2021).

**Figure 16:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity using Alternative Network Linkages



Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, based on alternative definitions of the production network. Results are reported for linkages fixed at their 2002 configuration and averaged across the sample period. Exposure is based on the overall EPS index and averaged across upstream and downstream linkages. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

Another robustness exercise considers alternative productivity measures. In addition to the baseline measure of real value added per employee from STAN, I also examine real value added per hour worked, nominal counterparts of both measures, and parallel measures derived from ICIO rather than STAN. Figure 17 shows that across all definitions, foreign climate policy exposure is associated with medium- to long-run productivity gains. The effects tend to be more pronounced when using nominal measures compared to real measures, suggesting that climate policy shocks not only raise real efficiency but also operate through relative price adjustments. Cleaner goods may command higher prices, or cleaner inputs may become more accessible and less costly, amplifying measured productivity in nominal terms. Since the focus of this paper is on real efficiency gains, I rely on real productivity per employee from STAN as the baseline measure. STAN is designed to align closely with national accounts, making it the more accurate productivity benchmark, whereas ICIO emphasizes consistency with input-output accounting and

therefore serves mainly as a robustness check. The stronger nominal responses nevertheless highlight price dynamics as an additional adjustment channel that complements the innovation and adoption mechanisms explored in Section 5.5 and merits closer investigation in future work.

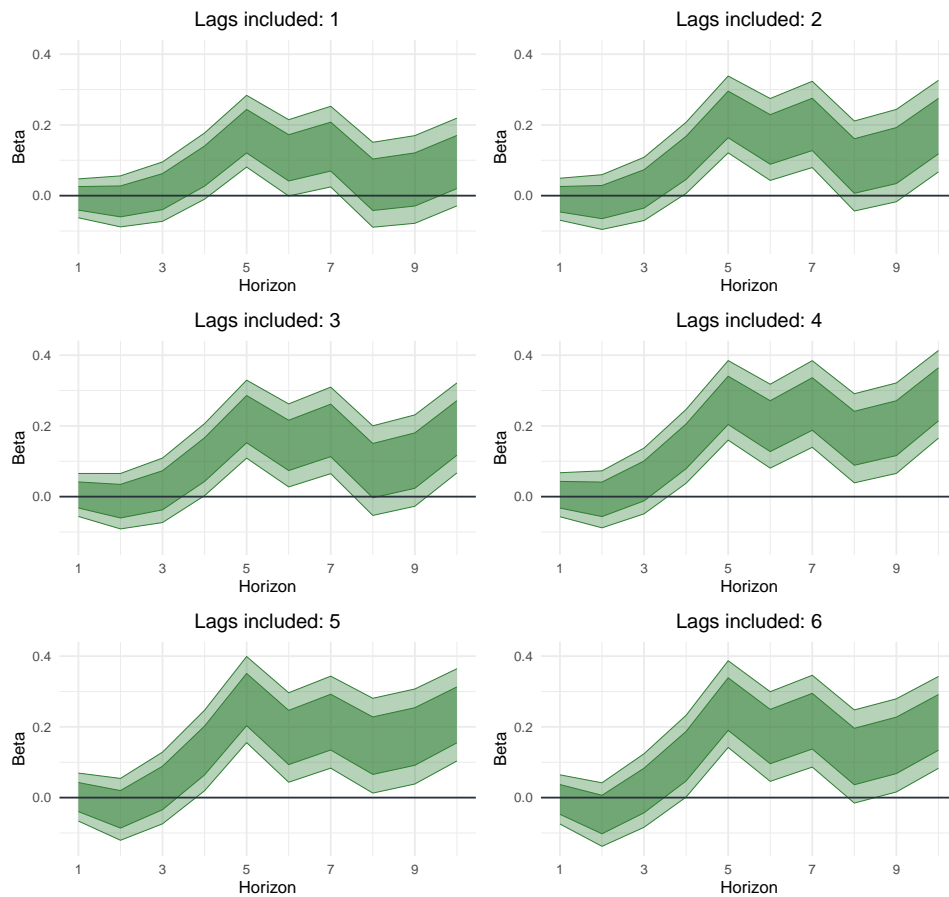
**Figure 17:** Dynamic Effects of Foreign Climate Policy Exposure on Alternative Productivity Measures



Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, based on alternative productivity definitions: real and nominal value added per person (p.p.) and per hour (p.h.) from STAN, as well as corresponding measures from ICIO. Exposure is based on the overall EPS index and averaged across upstream and downstream linkages. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

Finally, I test the robustness of the local projection framework to alternative lag structures. In dynamic panel settings, estimates may be sensitive to the number of lags included, since lag length affects how well serial correlation is absorbed and whether dynamics are properly captured rather than pushed into the error term. To address this, I re-estimate the baseline specification with all right-hand side variables lagged by between one and six periods. As shown in Figure 18, the results remain positive across all cases, with effects on average slightly more pronounced than in the baseline. This indicates that the documented productivity gains are not an artifact of the chosen lag structure but reflect a stable medium- to long-run response across alternative dynamic specifications.

**Figure 18:** Dynamic Effects of Foreign Climate Policy Exposure on Productivity under Alternative Lag Structures



Notes: The figure shows local projections of productivity responses to a one percent increase in exposure to foreign climate policies, estimated under alternative lag specifications ranging from one to six periods. Exposure is based on the overall EPS index and averaged across upstream and downstream linkages. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.



## 6 Conclusion

This paper has examined how climate policies enacted abroad spill over through global production networks and affect domestic industries. Using international input-output data and a granular instrumental variable strategy, I show that foreign policy stringency raises domestic productivity, with effects unfolding gradually rather than immediately. The results differ across policy types: market-based instruments and technology support measures generate clear productivity gains, while non-market regulations show little evidence of positive effects.

The analysis of underlying channels points to two main mechanisms. Foreign climate policies foster domestic green innovation, with stronger productivity gains in industries that are more active in patenting climate-related technologies. At the same time, they reduce the carbon intensity of intermediate inputs, suggesting that firms adapt by adopting cleaner inputs available through international supply chains. These mechanisms are related but distinct, pointing to a combination of new technology creation and the diffusion of existing ones.

Heterogeneity across industries reinforces this picture. Positive responses are concentrated in sectors that are pollution intensive, highly integrated into global value chains, and subject to stricter domestic policies. In such settings, both the incentives and the scope for adjustment are greater, allowing firms to translate foreign regulatory pressure into productivity improvements. By contrast, industries with weaker incentives or limited adjustment capacity display little evidence of change.

The findings speak to several ongoing debates. They add to the Porter hypothesis literature by showing that regulation abroad can contribute to domestic productivity growth, particularly when mediated through innovation and technology adoption. They also highlight that not all policy instruments are equal: market-based measures and technology support appear better suited to generating spillovers that support both productivity and cleaner production. Finally, the results suggest that international climate action should not be assessed solely in terms of domestic costs or competitiveness risks. When embedded in global value chains, foreign policies can become a source of efficiency

gains rather than a drag on performance.

From a policy perspective, this implies that concerns about competitiveness losses from unilateral climate action may be overstated. International spillovers can work in favor of regulated economies by fostering adjustment abroad and creating opportunities for productivity growth at home. Designing policies that strengthen these positive linkages, for example through technology cooperation, open trade in clean inputs, and supportive domestic frameworks, could amplify the benefits of climate action and accelerate the global low-carbon transition.

A brief note on scope and next steps. The input-output data used here lack bilateral input prices or markups at the country-industry link, so I cannot separate quantity from price pass-through. Future work could marry this design with product-level unit values or producer price indices to quantify price dynamics along the supply chain. In addition, sectoral reallocation surely plays some role that is not fully visible at the 44-industry aggregation; firm- or product-level data would help disentangle within-firm adjustment from between-firm reallocation and clarify how much of the gains reflect restructuring versus technological improvement.

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# Cross-Border Transmission of Climate Policies through Global Production Networks

## Appendix

**Table A1:** Country Coverage

<b>ISO3</b>	<b>Country</b>	<b>ISO3</b>	<b>Country</b>
AUS	Australia	AUT	Austria
BEL	Belgium	BRA	Brazil
CAN	Canada	CHE	Switzerland
CHL	Chile	CHN	China
CZE	Czech Republic	DEU	Germany
DNK	Denmark	ESP	Spain
EST	Estonia	FIN	Finland
FRA	France	GBR	United Kingdom
GRC	Greece	HUN	Hungary
IDN	Indonesia	IND	India
IRL	Ireland	ISL	Iceland
ISR	Israel	ITA	Italy
JPN	Japan	KOR	Korea
LUX	Luxembourg	MEX	Mexico
NLD	Netherlands	NOR	Norway
NZL	New Zealand	POL	Poland
PRT	Portugal	RUS	Russia
SVK	Slovakia	SVN	Slovenia
SWE	Sweden	TUR	Turkey
USA	United States	ZAF	South Africa

Notes: The country sample is restricted to those included in the OECD Environmental Policy Stringency Index.

**Table A2:** OECD Industry Classification Used in Inter-Country Input-Output (ICIO) Tables

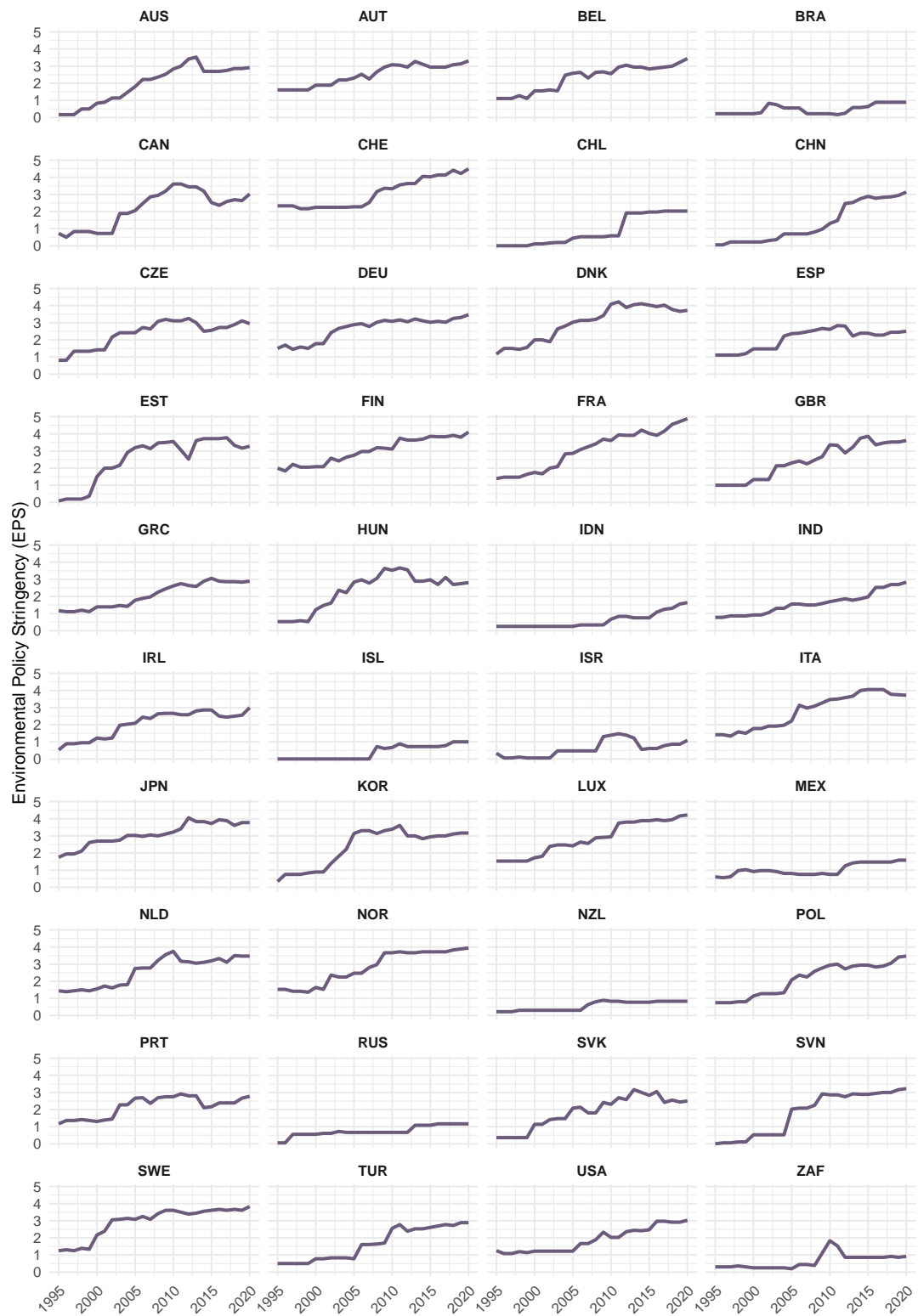
OECD Code	Industry	ISIC Rev.4
<b>Agriculture &amp; Extractives</b>		
A01_02	Crop and animal production, hunting and related service activities; Forestry and logging	01, 02
A03	Fishing and aquaculture	03
B05_06	Mining and extraction of energy producing products	05, 06
B07_08	Mining and quarrying of non-energy producing products	07, 08
B09	Mining support service activities	09
<b>Manufacturing</b>		
C10T12	Manufacture of food products; beverages and tobacco products	10, 11, 12
C13T15	Manufacture of textiles, wearing apparel, leather and related products	13, 14, 15
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	16
C17_18	Manufacture of paper and paper products; printing and reproduction of recorded media	17, 18
C19	Manufacture of coke and refined petroleum products	19
C20	Manufacture of chemicals and chemical products	20
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	21
C22	Manufacture of rubber and plastics products	22
C23	Manufacture of other non-metallic mineral products	23
C24	Manufacture of basic metals	24
C25	Manufacture of fabricated metal products, except machinery and equipment	25
C26	Manufacture of computer, electronic and optical products	26
C27	Manufacture of electrical equipment	27
C28	Manufacture of machinery and equipment n.e.c.	28
C29	Manufacture of motor vehicles, trailers and semi-trailers	29
C30	Manufacture of other transport equipment	30
C31T33	Manufacture of furniture; jewellery, musical instruments, toys, etc.; repair and installation of machinery and equipment	31, 32, 33
<b>Energy &amp; Utilities</b>		
D	Electricity, gas, steam and air conditioning supply	35
E	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39
<b>Construction</b>		
F	Construction	41, 42, 43
<b>Market Services &amp; Trade</b>		
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45, 46, 47
H49	Land transport and transport via pipelines	49
H50	Water transport	50

Notes: Concordance with ISIC Rev.4 is based on Yamano et al. (2023).

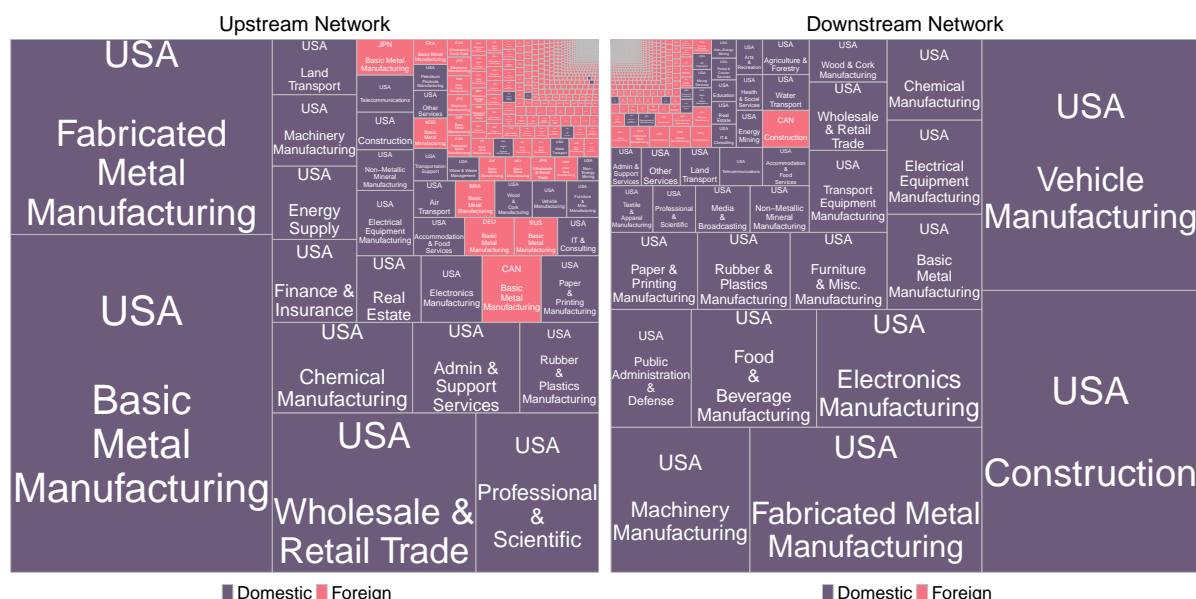
OECD Code	Industry	ISIC Rev.4
H51	Air transport	51
H52	Warehousing and support activities for transportation	52
H53	Postal and courier activities	53
I	Accommodation and food service activities	55, 56
J58T60	Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	58, 59, 60
J61	Telecommunications	61
J62.63	Computer programming, consultancy, and information service activities	62, 63
K	Financial and insurance activities	64, 65, 66
L	Real estate activities	68
M	Professional, scientific and technical activities	69 to 75
N	Administrative and support service activities	77 to 82
O	Public administration and defence; compulsory social security	84
<b>Knowledge, Public &amp; Other Services</b>		
P	Education	85
Q	Human health and social work activities	86, 87, 88
R	Arts, entertainment and recreation	90, 91, 92, 93
S	Other service activities	94, 95, 96

Notes: Concordance with ISIC Rev.4 is based on Yamano et al. (2023).

**Figure A1:** Environmental Policy Stringency Index by Country

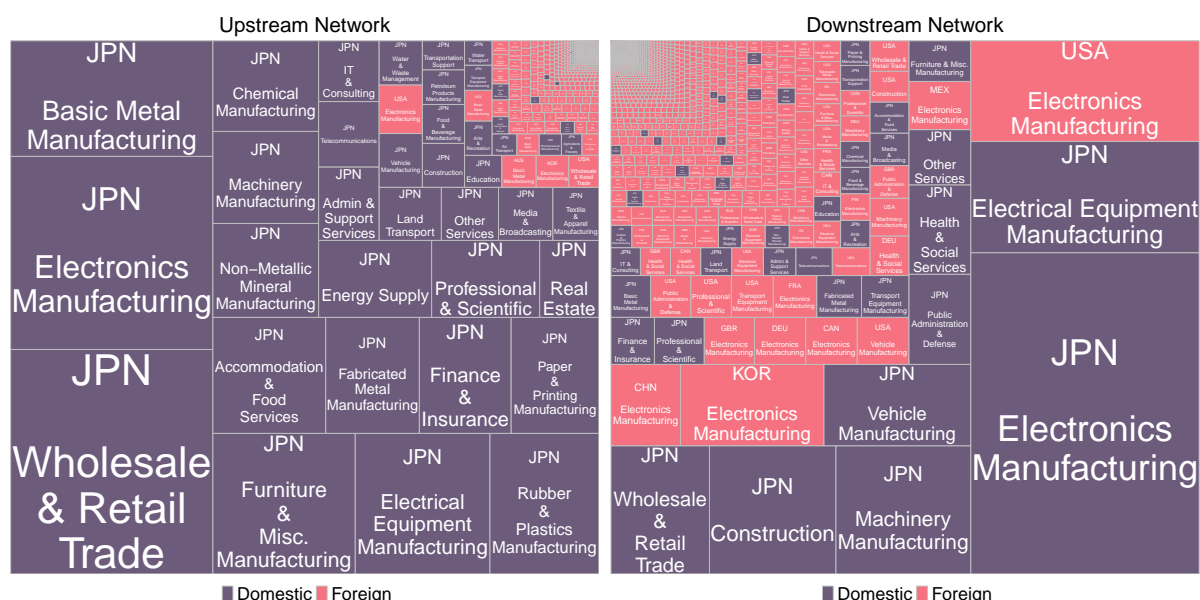


**Figure A2:** Upstream and Downstream Supply Chain Linkages of U.S. Fabricated Metal Manufacturing



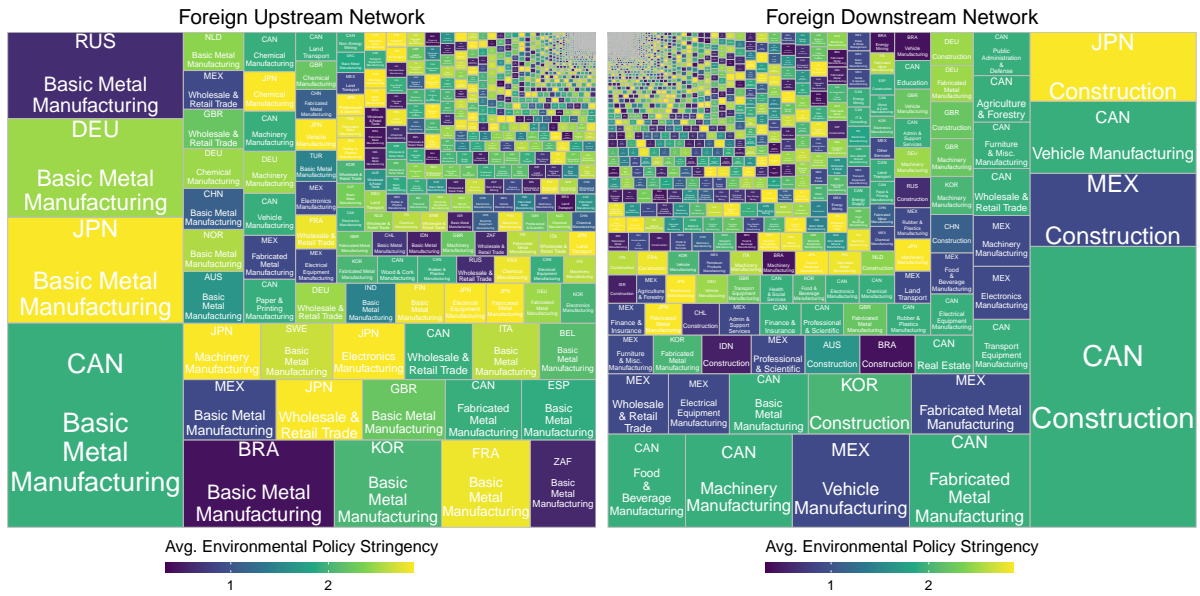
Notes: The size of each square reflects the relative importance of industries in the network: upstream suppliers in the left panel (inputs provided) and downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure.

**Figure A3:** Upstream and Downstream Supply Chain Linkages of Japanese Electronics Manufacturing



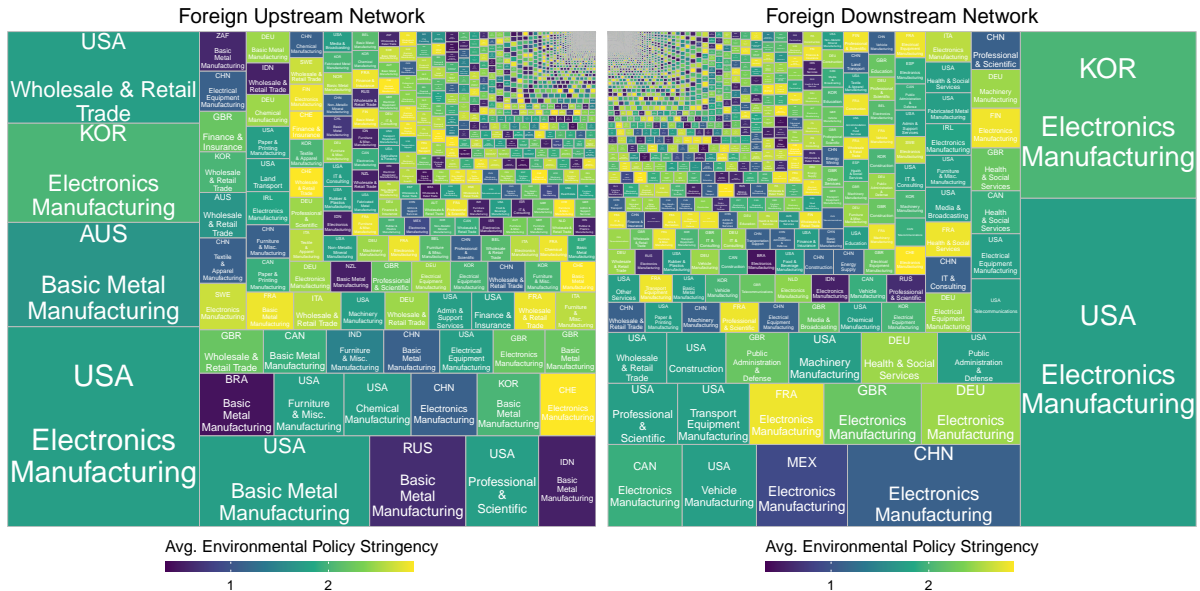
Notes: The size of each square reflects the relative importance of industries in the network: upstream suppliers in the left panel (inputs provided) and downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure.

**Figure A4:** Exposure to Foreign Climate Policy Exposure via Supply Chain Linkages for U.S. Fabricated Metal Manufacturing



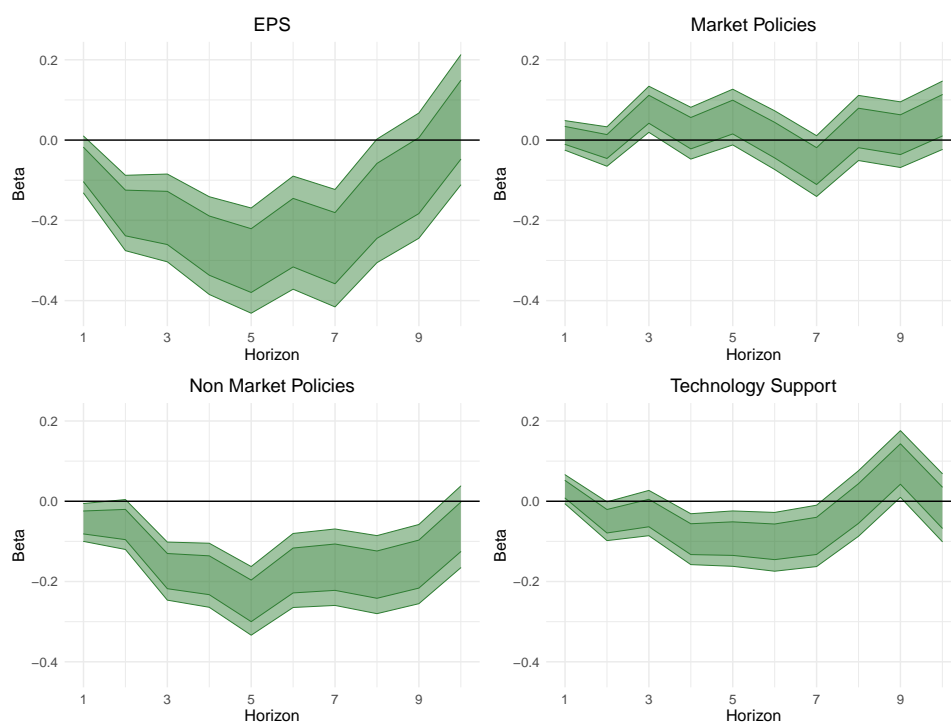
Notes: The size of each square reflects the relative importance of industries in the foreign network: foreign upstream suppliers in the left panel (inputs provided) and foreign downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure. Exposure is shown using the country-level environmental policy stringency (EPS) Index without carbon-intensity weighting; shading reflects the average stringency of partner countries' policies.

**Figure A5:** Exposure to Foreign Climate Policy Exposure via Supply Chain Linkages for Japanese Electronics Manufacturing



Notes: The size of each square reflects the relative importance of industries in the foreign network: foreign upstream suppliers in the left panel (inputs provided) and foreign downstream customers in the right panel (outputs absorbed). All production linkages are fixed at their 1995 structure. Exposure is shown using the country-level environmental policy stringency (EPS) Index without carbon-intensity weighting; shading reflects the average stringency of partner countries' policies.

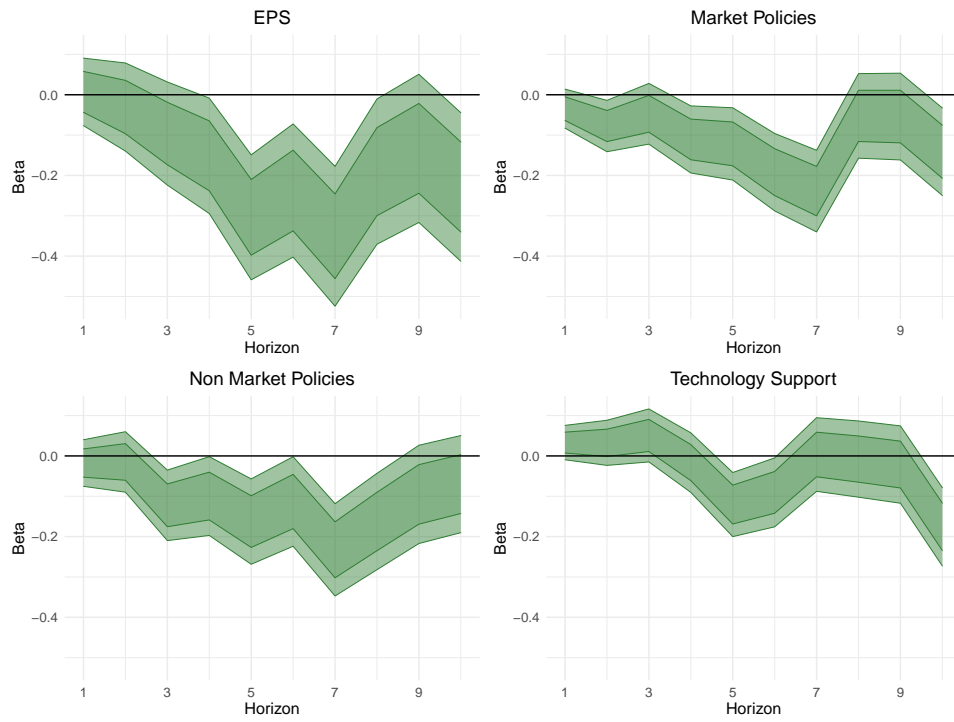
**Figure A6:** Dynamic Effects of Foreign Climate Policy Exposure on Carbon Emissions



Notes: The figure shows local projections of carbon emission responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

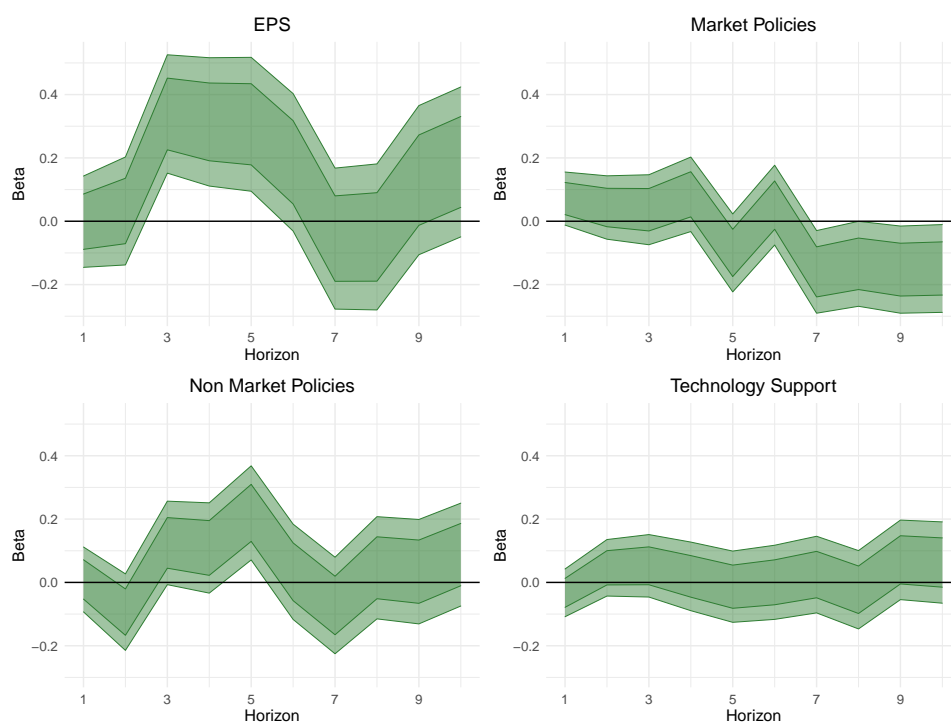


**Figure A7:** Dynamic Effects of Foreign Climate Policy Exposure on Carbon Intensity



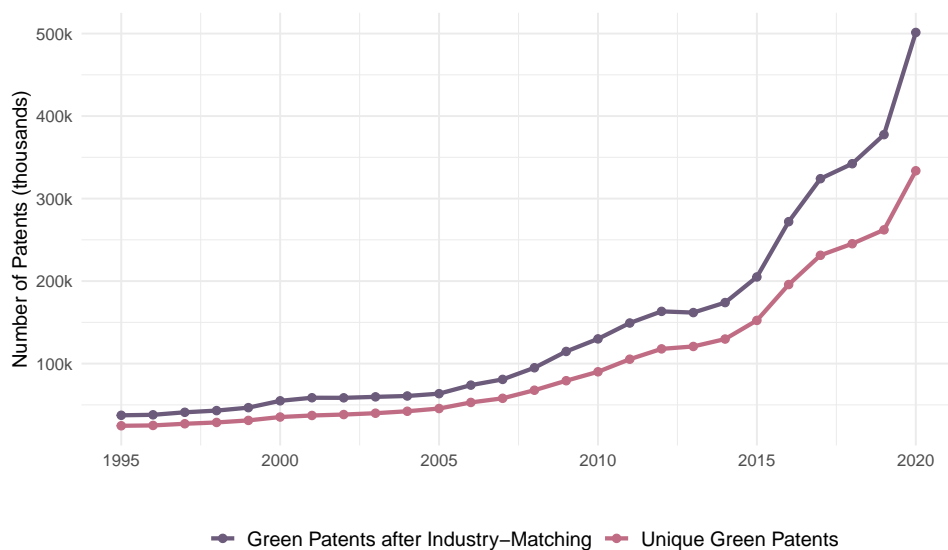
Notes: The figure shows local projections of carbon intensity responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

**Figure A8:** Dynamic Effects of Foreign Climate Policy Exposure on Capital Intensity



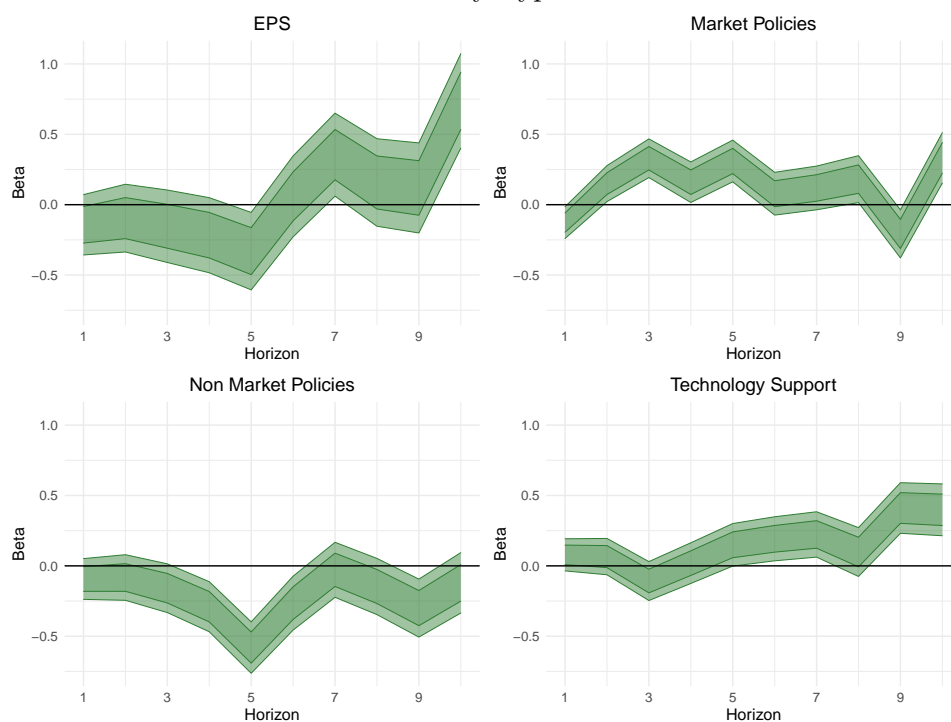
Notes: The figure shows local projections of capital intensity responses to a one percent increase in exposure to foreign climate policies, averaged across upstream and downstream linkages. Shaded areas denote 90 percent and 68 percent confidence bands, based on standard errors clustered at the country-industry level.

**Figure A9:** Evolution of Green Patents over Time



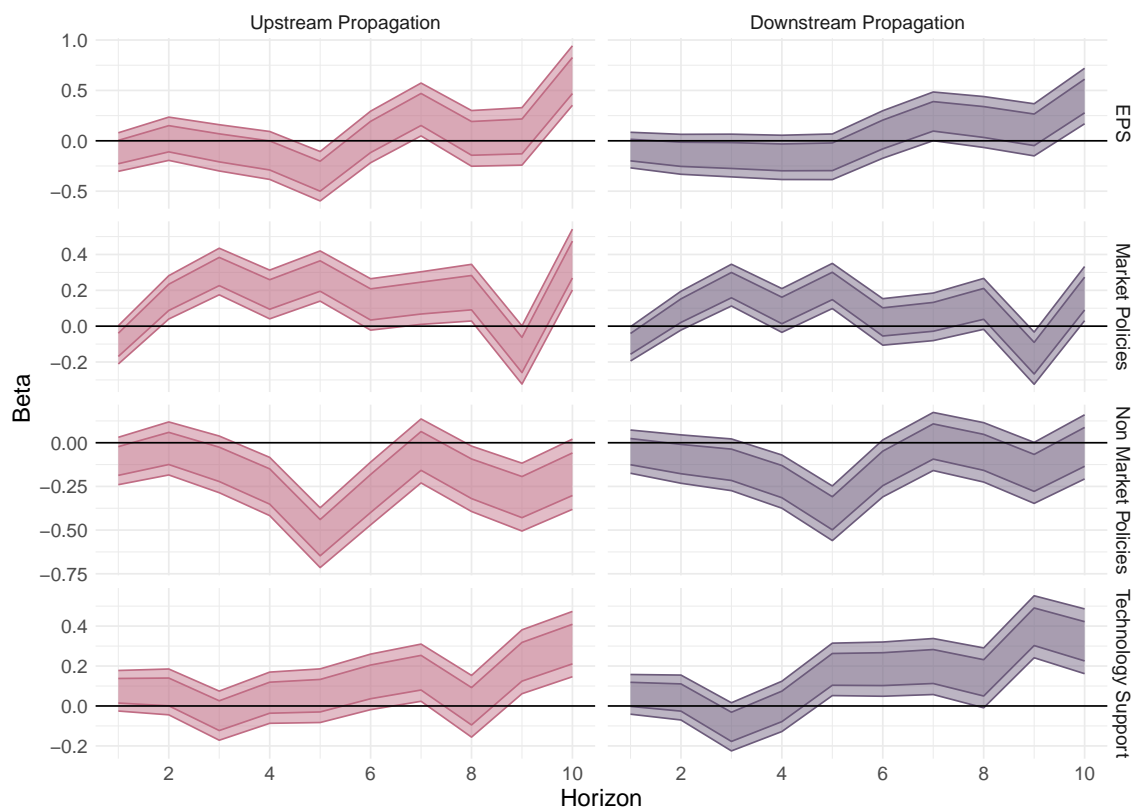
Notes: Green patents are defined according to PATSTAT's Y02 classification of climate change-mitigating technologies. Patents may be assigned to multiple industries because a single application can contain several IPC codes, which are concorded to ISIC Rev.4 industries.

**Figure A10: Dynamic Effects of Foreign Climate Policy Exposure on Green Patenting by Policy Type**



Notes: The figure shows local projections of green patenting responses to a one percent increase in exposure to foreign climate policies, based on the EPS index and disaggregated by policy type. Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

**Figure A11:** Dynamic Effects of Foreign Climate Policy Exposure on Green Innovation by Supply Chain Channel and Policy Type



Notes: The figure shows local projections of green patenting responses to a one percent increase in exposure to foreign climate policies. The left panel displays upstream exposure (via foreign suppliers), and the right panel downstream exposure (via foreign customers). Shaded areas denote 90 and 68 percent confidence bands, with standard errors clustered at the country-industry level.

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