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Services trade and Environmental Sustainability: Conceptual linkages and empirical patterns

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Services trade can shape the scale of economic activities, their composition, and production techniques, all with implications for environmental sustainability. Yet, the economic literature has paid limited attention to the linkages between services trade and the environment. This paper aims to fill this gap by exploring both conceptually and empirically the role of services trade in the green transition. Country-level analysis shows that greater imports of services across a broad range of sectors – including core environmental services as well as environmentally related services such as research and development, engineering, and architecture - are associated with higher environmental performance. Robust estimates based on a sample of 49 countries and 17 manufacturing sectors over the period 2014-2018 indicate that reducing policy restrictions on imported services inputs lowers the emission intensity of downstream manufacturing. In addition, the analysis reveals that environmental policy stringency increases services imports. Overall, the paper demonstrates that services trade policy can contribute to addressing environmental challenges and that synergies with environmental policy should be considered.

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Key messages

- **Services trade can affect the environment through multiple channels.** Increased services trade *expands economic activities*, which, all else being equal, may heighten pressures on resources and raise pollution levels (scale channel). Services trade may also *alter the composition of economic activities*, potentially increasing or reducing environmental risks depending on the specialisation path an economy adopts as it becomes more open to services trade (composition channel). Moreover, services trade can *foster technological advancements and solutions* that reduce the environmental footprint of economic activities (technique channel). This latter channel provides a compelling rationale for viewing services trade as a key driver in accelerating global progress toward environmental sustainability.
- **Higher imports of services and lower restrictions on services trade are associated with stronger environmental performance in OECD economies and accession candidates.** This relationship holds across many services sectors, including those targeted by recent policy efforts to promote services trade as a driver of the green transition. These sectors encompass core environmental services as well as environmentally related services such as research and development, engineering, and architecture. Descriptive evidence supports the hypothesis that services trade has a positive environmental effect through the technique channel, highlighting the need for more robust and targeted analyses to establish strong causal linkages.
- **Lower trade restrictiveness affecting services used as intermediate inputs in production processes significantly decreases emission intensity in downstream manufacturing sectors.** Ambitious yet realistic policy reforms that remove regulatory barriers to services trade are estimated to reduce carbon dioxide (CO₂) emission intensity by an average of 1.5% across manufacturing sectors. This is particularly pronounced in the more polluting manufacturing sectors and in countries with lower per capita GDP, highlighting the potential role of services trade policy in promoting convergence toward higher environmental performance across countries and sectors.
- **Environmental policy stringency creates incentives to seek services necessary to meet higher environmental standards in international markets.** Increased environmental stringency—in particular through higher performance standards and more stringent international co-ordination policies—leads to greater reliance on imported services rather than domestic suppliers. This pattern is especially pronounced in sectors such as financial, maintenance and repair, telecommunications, and other business services.
- **Environmental policy can influence how services trade affects the environment in different ways.** Focusing on the technique channel, the same imported service can have a stronger sustainability impact in countries with stricter environmental regulations, as these encourage its use to support environmental solutions and meet higher standards. Conversely, services imports can also yield greater environmental benefits in countries with weaker regulations, where such regulations reflect domestic contexts with fewer tools to address environmental challenges. In these contexts, imported services can play a more substantive role in fostering environmental solutions. Preliminary estimates confirm that both mechanisms can be at play. Context-specific analysis can help policymakers prioritise and co-ordinate efforts between environmental and services trade policies.

1 Introduction

Many challenges exist to combining increased economic activity with environmental sustainability. Services and services trade are recognised as potential facilitators of the green transition. Services, representing two-thirds of global output, are among the most dynamic sectors in international trade (WTO, 2019^[1]), incorporating and generating value added in international supply chains.

Services trade can shape the scale and specialisation of economies, with implications for environmental sustainability. It can support the development and adoption of green production methods and contribute to end-of-pipe pollution control or to the prevention of environmental degradation. It can facilitate the implementation of environmental projects and help in the production of environmental goods. Yet despite the increasing number of hypotheses and case studies on the multiple roles services trade can play for environmental sustainability, there is little attention in the economic literature on the linkages between services trade and the environment. In view of increasing efforts by trade negotiators to promote environmental sustainability through services trade policy,¹ it is important to raise awareness of these linkages.

This paper aims to support policy discussions by exploring conceptually and empirically the role of services trade in the green transition. The analysis investigates the linkages between trade in different types of services, from engineering to transport, from financial to maintenance and repair services, and environmental performance at the country and sector levels.

The mechanisms through which trade in services affects the environment are analysed using the classic scale, composition, and technique (SCT) framework established by Grossman and Krueger (1991^[2]). This approach highlights that the strongest case for a positive environmental impact of services trade lies in the technique channel—namely, its role in facilitating technological advancements that mitigate or remediate environmental risks across economic activities.

Building on the SCT framework, the present analysis proposes several empirical exercises to test whether and how the data support the existence of a positive environmental effect of services trade through the technique channel. A first broad yet descriptive exercise for OECD economies and accession candidates provides *prima facie* evidence that higher services imports—or lower trade restrictions—are linked to stronger environmental performance, particularly in climate change mitigation and adaptation, circular economy promotion, and biodiversity protection.

This positive correlation is especially strong for key services such as R&D, professional and management consulting, technical and scientific services (including architecture and engineering), and core environmental services. Notably, higher services imports are strongly associated with greater energy

¹ Several trade agreements and plurilateral initiatives are addressing services trade policy as a core dimension of their effort towards environmental sustainability. At the WTO, the Trade and Environment Structured Discussions (TESSD) provide a forum to address environmentally related services (see [WTO | Trade and environmental sustainability](#)). Other initiatives include the development of a new list of environmentally related services under APEC, which has been incorporated into the schedules of commitments in the Singapore-Australia Green Economy Agreement (SAGEA) (see [Annex 2 - Reference List of Environmental and Environmentally Related Services | 2021 APEC Ministerial Meeting | APEC](#)). The Agreement on Climate Change, Trade and Sustainability (ACCTS) is another key initiative in this space ([Agreement on Climate Change, Trade and Sustainability \(ACCTS\) | New Zealand Ministry of Foreign Affairs and Trade \(mfat.govt.nz\)](#)). For a comprehensive assessment of services trade policy in support of environmental sustainability, see Morard (2024^[91]). Bellmann and Bulatnikova (2022^[92]) further provide a focused analysis of how environmental provisions are and can be incorporated in chapters and articles of regional trade agreements dealing with trade in services.

productivity, higher recycling rates, and lower GHG emission intensity in industrial processes. Likewise, positive correlations across nearly all sectors between services imports and green innovation indicators suggest a strong technique channel at play. Lower regulatory restrictions on services trade are empirically associated with better environmental performance, particularly for architecture, engineering, and telecommunications services. This relationship holds across various environmental indicators, including pollution intensity measures. Among these, GHG emission intensity in industrial processes shows the strongest positive correlation with open services trade policies and environmental sustainability performance.

A second, more econometrically ambitious exercise exploits input-output linkages between upstream services and downstream manufacturing to assess the technique-driven impact of services trade along value chains. Robust estimates based on a sample of 49 countries and 17 manufacturing sectors over the period 2014-2018 show that reducing restrictions on imported services inputs lowers the emission intensity of downstream manufacturing production. A quantification exercise indicates that ambitious yet realistic policy reforms removing regulatory barriers to services trade reduce CO₂ emission intensity by an average of 1.5% across manufacturing sectors. These impacts are economically sizable, considering that the total decline in average CO₂ emission intensity across sectors over the period was 7%, on average across the countries analysed. Moreover, the estimates suggest that the liberalisation of upstream services sector fosters cross-sectoral convergence in downstream manufacturing environmental performance; countries with greater reform potential or lower development levels are predicted to experience larger reductions in CO₂ emission intensity.

Finally, this paper explores the role of environmental policy in shaping the relationship between services trade and environmental performance. The literature on globalisation and the environment show that environmental policy is a key factor in influencing the trade-environment sustainability nexus (Copeland, Shapiro and Taylor, 2022^[3]). The results presented here show that strict environmental policies increase services imports, demonstrating how international services can contribute to higher environmental standards. However, further empirical analysis reveals that higher environmental stringency is not consistently associated with a stronger effect of services trade on environmental sustainability, underscoring the complex interplay of complementarity and substitutability between services trade and environmental policies.

This paper is structured as follows. Section 2 builds on the existing literature on the linkages between trade and the environment to introduce a framework used to conceptualise the relationship between services trade and environmental sustainability. Section 3 presents empirical analysis on the role of services trade on both environmental performance at the country level and the emissions intensity of manufacturing sectors further downstream of supply chains. Section 4 focuses on the role of environmental policy and Section 5 concludes.

2 Services trade and the environment: Conceptual framework

Concerns on the environmental impact of trade have sparked debate over whether trade has a positive or negative effect on environmental sustainability. Both theory and data suggest this relation is complex and the impact of trade on the environment varies.² This section focuses on the role *services trade* can have in promoting environmental sustainability.

To analyse the effects of trade on the environment, the economic literature has developed and refined a framework consisting of three main impact channels: scale, composition and technique (SCT) (Grossman and Krueger, 1991^[2]). Any economic activity and its environmental footprint will vary depending on its scale, the relative importance of its components with different environmental impact, and the technique used to carry it out. For many economic activities, trade can influence all three parameters, meaning its environmental impact can potentially operate through all these channels: by shaping the scale of economic activities, their composition, and their technique.

Applying the SCT framework involves structuring the analysis of the environmental effect of trade around three questions. How does trade shape the scale of the economic activity in question? What are the effects of trade on the relative share of the activity's elements with different environmental footprints? How does trade influence the techniques used to carry out the activity? While the SCT framework is widely used in the literature to study the environmental impact of overall trade and trade in goods, its application to services trade is rare.³ It is nevertheless well-suited to assess the environmental effects of services trade by helping to identify the main mechanisms and patterns of impacts across various dimensions of environmental sustainability.

To illustrate this, consider gross domestic production of goods and services as the economic activity of interest. Increased imports of services (e.g. financial, engineering, transport, and logistics) could enable firms to access higher quality-to-price ratio services from international markets, thereby reducing firms' design, operational, and distribution costs, leading to scaled-up production. All else being equal (including the relative contribution of each sector to total output and the production techniques used across sectors), a higher scale of production would increase its environmental footprint as measured, for example, by production-based emissions. This negative effect of services trade on the environment operates via the *scale* channel.

² For instance, Antweiler, Copeland and Taylor (2001^[69]) find that emissions increase as GDP rises and decreases with trade openness. Frankel and Rose (2005^[81]) use an instrumental variable strategy to control for the reverse causality between trade and environmental sustainability and find that trade reduces the level of SO₂ emissions. In contrast, Cole and Elliott (2003^[82]) find a negative relationship between income and emissions and a positive relationship between trade openness and emissions. A growing empirical literature at the firm level looks at how accounting for reallocation across firms changes the analysis of trade and the environment (Cherniwchan, 2017^[78]; Barrows and Ollivier, 2018^[79]; Shapiro and Walker, 2018^[80]).

³ Liang and Hao (2023^[70]) present several hypotheses on the role of services trade for carbon emission reduction using a framework similar to the classic SCT framework employed here. Important differences distinguish the work of these authors from the present paper. Liang and Hao (2023^[70]), for example, discuss the direct effect of services trade on emissions related to the trade-induced expansion of the services sector, labelling it as the scale effect of services trade. However, their approach is by construction narrower than the standard conceptualisation of the scale channel. Indeed, instead of discussing whether and how services trade can expand the scale of aggregate national production, consumption, or other economic activity, they argue that services trade increases the size of the domestic services sector. This assumption crucially depends on the patterns of comparative advantage, which are outside the remit of their discussion. Ibrahim, Sari, & Handoyo (2021^[88]) also present a study using the SCT framework, with an empirical application to African countries.

Services trade may affect the production of goods differently than the production of services, thereby shaping the composition of total output. For example, if services trade disproportionately favours the expansion of services output compared to goods, and if the emission intensity in services is lower than in manufacturing sectors, then, assuming the overall scale and technique of production remain constant, the environmental footprint of gross domestic product will decrease with higher services trade through the *composition* channel.

Finally, increased services trade (for instance higher imports of state-of-the-art engineering and consulting services) may lead to the development and adoption of more energy efficient production methods across sectors, thereby lowering the environmental footprint of production for a given scale and composition. The effect of services trade on the environment operates here through the *technique* channel.

The remainder of this section discusses how trade in services can affect the environment via these three channels.

2.1. The impact of services trade through the scale channel

Trade increases the levels of production, transportation, and consumption of goods and services. Assuming constant composition and technique channels, increased scale of economic activities exerts greater pressure on the environment as more inputs and resources are required and higher levels of pollution are generated. Both manufacturing and services trade have the capacity to increase the scale of economies. Even though the linkages between economic growth and services trade (or services trade openness) have been relatively less investigated than for the case of trade in goods, there is a comprehensive body of research identifying mechanisms and building solid empirical evidence in support of a positive effect of services trade on growth.

Several early studies have shown the positive impact of services trade openness on economic growth in cross-country regression frameworks (Eschenbach and Hoekman, 2006^[4]; Mattoo, Rathindran and Subramanian, 2006^[5]). Expanding opportunities to export services can push firms to adopt innovative strategies to compete in foreign markets, including by combining goods and services in new export bundles (Vandermerwe and Rada, 1988^[6]; Baines et al., 2009^[7]; Cadestin and Miroudot, 2020^[8]), ultimately leading to higher production levels. However, the most robust analyses demonstrating a strong positive effect of services trade on economic growth are those that examine and test the characteristics of various service activities in improving efficiency, productivity, and overall economic performance across all sectors of the economy.

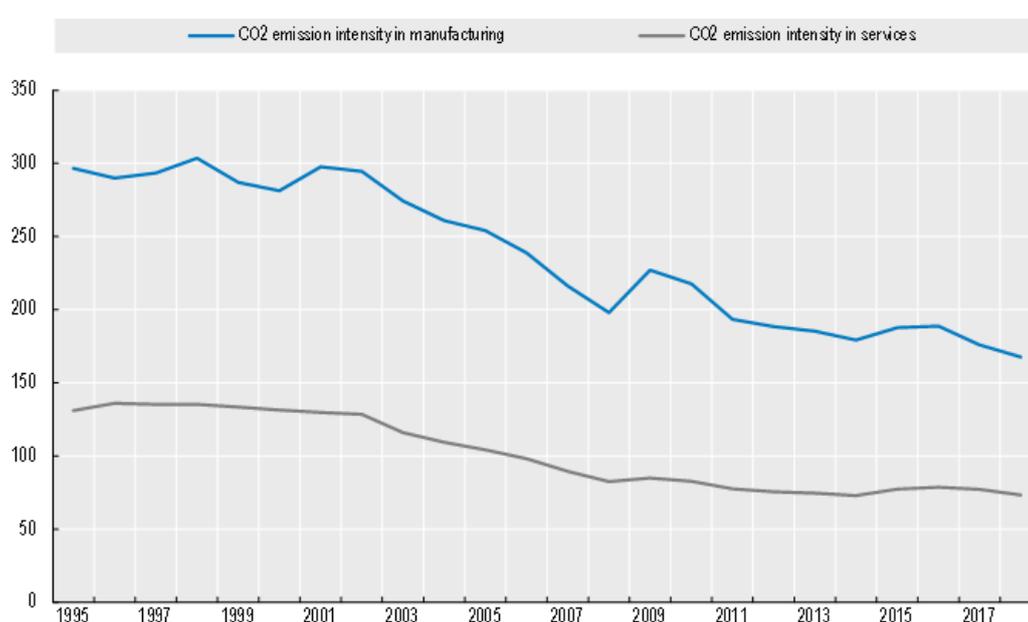
Certain services enhance the productivity of essential factors of production like capital (e.g. through research and development and engineering) and labour (via health and education) (Francois and Hoekman, 2010^[9]). Many other services are fundamental inputs to virtually all production processes and value chains, from design, to logistics, to distribution (Francois, 1990^[10]; Low, 2013^[11]). Financial services are vital for channelling savings into business investments. Other services, such as transport, telecommunications, and computer services, support the movement of goods, people, and information. Additionally, business services such as accounting and legal services reduce firms' transaction costs (Fiorini and Hoekman, 2018^[12]). With growing services tradability (Benz, Jaax and Yotov, 2022^[13]), trade (imports) is an increasingly important factor allowing economic actors to improve their access to these activities. Therefore, services trade can increase the scale of the entire economic system and, through the scale channel, the pressures exerted on the environment.⁴

⁴ The empirical evidence on the effects of higher access to or use of services on the economic performance of firms and sectors across entire economic systems is vast. For a recent review, see Benz et al. (2023^[39]). There is also extensive literature showing that importing foreign goods plays an important role on the exporting capacity of firms,

2.2. The impact of services trade through the composition channel

Trade may affect the composition of economic activities. This is the case for national output where trade openness can disproportionately favour the expansion of some economic sectors while limiting others, thereby altering the intensity, type, and level of environmental pressures across regions and countries. The environmental effects of trade through this composition channel are either positive or negative depending on the patterns of comparative advantage and services trade-induced specialisation. Considering CO₂ emissions embedded in production, services sectors are generally less polluting than manufacturing (Figure 1). Therefore, all else being equal, a country where services trade openness leads to specialisation in services sectors will become relatively less polluting compared to a country where services trade-induced specialisation leads to a reallocation of resources towards manufacturing.

Figure 1. Emission intensity in manufacturing and services sectors



Note: Emission intensity is computed as a share of total emissions on total output (tonne CO₂ per USD million) for manufacturing and services sectors. The figure covers 65 countries, 17 manufacturing sectors and 13 services sectors.

Source: Author's elaboration using OECD TiVA TECO₂ database.

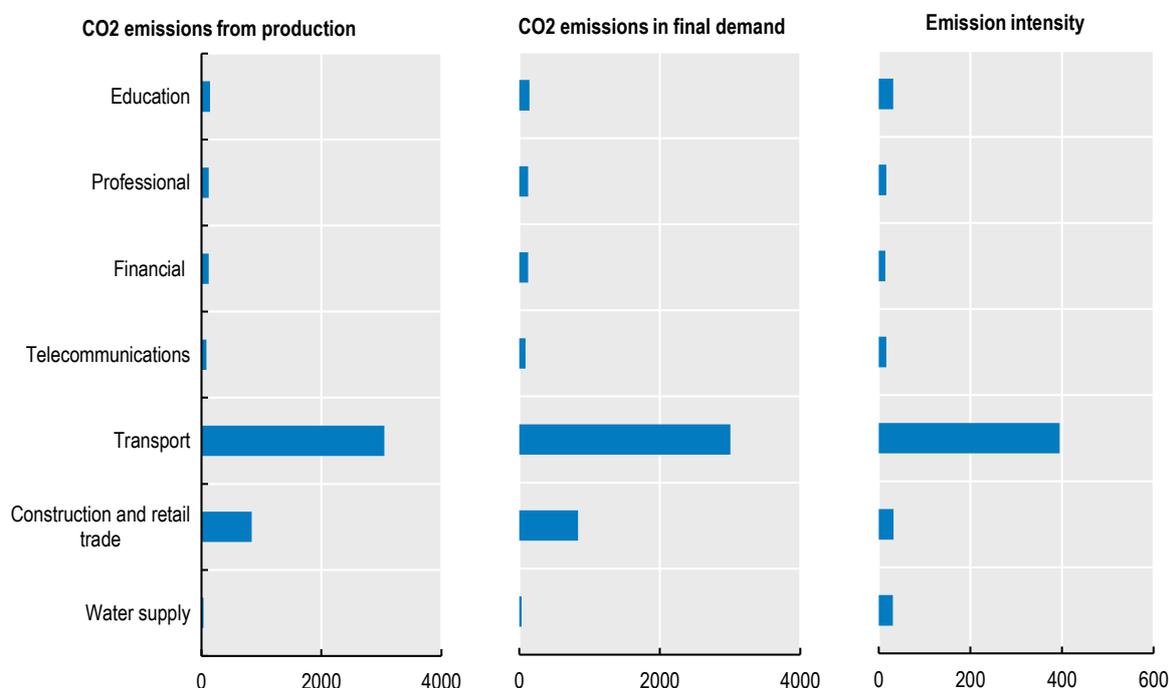
Given the varying environmental footprints across sectors, specialization in one service sector over another will affect the environmental impact of services trade through the composition channel. Figure 2 shows that some services sectors, e.g. transportation, construction, and retail trade, are more polluting both in terms of overall CO₂ emissions from production (left panel) or from consumption⁵ (central panel) and in terms of CO₂ emission intensity (right panel). Assessing the effect of services trade on environmental sustainability through the composition channel raises an important question: how does trade in services

leading to growth via a reduction in costs of production or an increase of productivity due to more input varieties available from international markets (Bernard et al., 2007^[83]; Goldberg et al., 2010^[84]; Bas and Strauss-Kahn, 2013^[85]; Amiti and Konings, 2007^[86]).

⁵ Production-based CO₂ emissions account for all emissions generated within a country's borders from producing goods and services, while consumption-based emissions attribute CO₂ to the final consumer, including emissions from imported goods.

affect the composition of economic activities with respect to elements that have varying environmental footprints?

Figure 2. CO2 emissions from different types of services



Note: Emissions are expressed in tonnes of CO2. The analysis covers 65 countries, 17 manufacturing sectors and 13 services sectors. Source: Author's elaboration using OECD TiVA TECO2 database.

The answer depends on a complex web of interactions between the role services play in specific economic systems and the patterns of comparative advantage across countries and services sectors. Exploring these interactions is challenging. For the purposes of this paper, several key features that characterise the environmental implications of any pattern of specialisation driven by services trade are highlighted.

- *Intangibility*: Services are intangible and often require direct interaction between the provider and consumer. As such, the environmental implications of specialisation driven by services trade are likely to shape the relative importance of the physical production compared to the processes and infrastructures that support service delivery. These components can exert very different pressures on the environment.
- *Digitalisation*: Services trade can shape the extent to which an economic system relies on digital activities, with implications for, for instance, the relative importance of physical travel and related infrastructures compared to the framework for digital delivery applying to services. The debate on the net environmental impact of digitalization remains open.
- *Servicification*: Trade in services can affect the “servicification” of economic systems, denoting the pattern in production activities to (increasingly) rely on services, both as inputs and outputs sold as a complements or substitutes for manufactured goods (National Board of Trade, 2012^[14]; National Board of Trade, 2016^[15]). In so far as activities with a higher degree of servicification have lower environmental impacts, services trade can affect environmental sustainability through the composition channel by changing the relative share of these activities in the economy.

Overall, the transformation in the composition of economic activities brought about by opening trade in services can either increase or decrease the economic pressures exerted on the environment.

2.3. The impact of services trade through the technique channel

One of the main findings in the literature on globalisation and the environment is that the technique channel is the primary mechanism through which trade positively impacts environmental sustainability (Copeland, Shapiro and Taylor, 2022^[3]). This is due to the role of trade in promoting innovation by enabling access to technology, knowledge, and knowhow. Several empirical studies, along with a growing body of qualitative evidence and case studies, suggest that similar, if not stronger, forces are at play for services trade.

Services are key to virtually any technical solution that will make economic activities more environmentally sustainable. Environmental services such as wastewater treatment, the collection and management of hazardous and non-hazardous waste, remediation services, sanitation and similar services, and other environmental protection services are considered traditional environmental solutions that allow economic systems to successfully target pollution prevention, control and abatement objectives. While these activities continue to be important, the fast pace of technological change and the ambition to accelerate the green transition across all segments of the economy highlight the environmental function of a broader range of services activities (Sauvage and Timiliotis, 2017^[16]).

Engineering, computer, and telecommunications services are vital for driving innovation that enhances environmental sustainability across sectors and facilitates their integration into industrial and commercial applications. On the ground, the circular economy relies heavily on material reuse and recycling, involving the distribution sector alongside transport and logistics services. Architecture and construction services play a key role in improving energy efficiency and designing the infrastructure needed for the green transition. Financial services—such as advisory, project financing, insurance, and risk management—support investments in green technology.

Trade serves as a key mechanism for making these and other services accessible worldwide, fostering technical advancements that promote more efficient use of natural resources and improving access to solutions that mitigate or remediate the environmental impacts of economic activities.⁶

However, the effectiveness of knowledge and technology diffusion through the technique channel also depends on factors beyond trade. A critical factor is absorptive capacity—the ability to effectively utilise foreign knowledge and technology in specific contexts—which can be influenced by elements such as human capital, technological development, and engagement with local indigenous knowledge (Saliola and Zanfei, 2009^[17]). Box 1 explores how indigenous knowledge can enhance the impact of imported services on the domestic environment. Additional factors supporting international technology diffusion include domestic investment (Keller (2004^[18]); Hötte (2020^[19])) and complementarity between domestic and foreign inputs.⁷

⁶ Several empirical studies support some of the mechanisms motivating expectations for a strong, positive impact of services trade on the environment through the technique channel. Kalantzis (2022^[74]) finds that financial services can facilitate the implementation of measures for climate change mitigation at the firm level; Martin et al. (2012^[76]) and Blass et al. (2014^[77]) illustrate empirically that more open access to training services, in particular at the managerial level, can support the adoption of climate-friendly management practices; Fang, Huo and Hatim (2023^[75]) use Chinese firm level data to show that digital services trade liberalisation can improve the quality of green innovation, by increasing green R&D expenditure and strengthening information sharing; Liang and Hao (2023^[70]) provide positive estimates of the effect of services trade on carbon emission reduction across Chinese provinces via the technique channel. Selected qualitative case studies that showcase the role of services in enabling and supporting technical solutions for more environmentally sustainable economic activities can be found in Table A A.1.

⁷ For instance, adoption of climate adaptation technologies in developing countries depends on complementary inputs, as shown in studies of agricultural innovations (Tambo and Abdoulaye (2011^[89]) and Badi et al. (2020^[90])).

Finally, foreign direct investment and mechanisms like the Clean Development Mechanism promoting technology transfer in developing countries are tools that may enhance a better technique effect of trade (Dechezleprêtre, Glachant and Ménière, 2008^[20]).⁸ Domestic policies such as government support for R&D in clean technologies, complemented by environmental policy instruments such as temporary taxes, emissions trading systems, and energy price adjustments can redirect innovation towards clean inputs and low-carbon technologies and play a role in improving environmental performance (Acemoglu et al. (2012^[21]), (Calel and Dechezleprêtre (2016^[22])).

Box 1. Indigenous knowledge and the technique channel of services trade impact

Indigenous knowledge can amplify the positive environmental impact of services trade. Many Indigenous Peoples have a profound relationship with their environment, shaping knowledge and environmental practices over millennia (World Economic Forum, 2024^[23]). Given that indigenous knowledge is highly localised and unique, it can be useful for the development of policies for environmental sustainability such as those related to climate change adaptation, resilience, and disaster preparedness (Makondo and Thomas, 2018^[24]). This intimate understanding, combined with the innovation, knowhow, and expertise inherent in state-of-the-art services sourced from international markets, can lead to the adoption of more environmentally sustainable practices.

The City Rail Link (CRL), New Zealand's largest urban infrastructure project, exemplifies this synergy.¹ Designed to support Auckland's sustainable growth, the CRL will improve the public transport infrastructure in the country's economic hub (Burke, 2021^[25]). Vinci Construction, a French group, leads the alliance contracted to deliver the underground rail tunnel (City Rail Link, 2024^[26]). The Indigenous Māori are integral to this project, contributing to regular monitoring and decision-making, with Māori knowledge and values central to managing the impact of the project on the environment (City Rail Link, 2024^[26]).

The CRL adapted the Infrastructure Sustainability Council's (ISC)² Infrastructure Sustainability Rating Scheme by incorporating Māori knowledge and values, such as the responsibility to future generations, to evaluate, improve and verify sustainability performance (Infrastructure Sustainability Council, 2024^[27]). This approach has earned the CRL multiple ISC awards, including for sustainability-related leadership in the segment of the project lead by Vinci Construction (Infrastructure Sustainability Council, 2024^[27]). Vinci Construction has shared its knowledge and skills through employment, training, and the creation of supply chain opportunities for Māori (Vinci, 2024^[28]). This complementary relationship where Māori knowledge and values contribute to the sustainable delivery of the CRL and the technical expertise of Vinci Construction offers pathways for social, economic, and technical development for Māori.

Another example is found in British Columbia, Canada, where the government acknowledges Indigenous Peoples' unique environmental insight. Indigenous participation is mandated throughout the environmental assessment process - from design to post-assessment phases - for projects with potentially significant adverse sustainability impacts (Government of British Columbia, 2024^[29]). For those projects that have been approved, Indigenous involvement often continues throughout its implementation and even beyond.

Central to both examples is the importance of regular and ongoing consultation and engagement with Indigenous Peoples. Such collaboration can enable environmentally significant projects to harness the

⁸ A detailed description of the Clean Development Mechanism is available at: <https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism>.

technical innovation and expertise of foreign services providers by leveraging Indigenous Peoples' unique insights on the local environment.

1. The CRL is part of a broader transport plan that includes the electrification of Auckland's rail network (Auckland Transport, 2016[91]). With renewable energy also providing around 87% of New Zealand's electricity, the CRL will mean more sustainably powered electric trains connecting Auckland's public transport network (New Zealand Ministry of Business, Innovation & Development, 2023[92]).
2. The Infrastructure Sustainability Council works in Australia and New Zealand to enable sustainable outcomes in infrastructure development by offering the Infrastructure Sustainability rating scheme, providing education, connecting suppliers of sustainable products, bringing together experts, and recognising and awarding best practices.

2.4. Discussion

When composition and technique channels are fixed, trade in services is likely to increase the scale of economic activities, thereby exerting a negative effect on the environment via the scale channel. From a theoretical standpoint, the environmental impact of services trade via the composition channel is ambiguous. Increased openness to services trade could lead to greater or reduced environmental degradation depending on the specialisation path a country takes as a result of higher trade openness. In contrast, the conceptual mechanisms underlying the linkages between services trade and environmental sustainability that could materialise via the technique channel strongly suggest a positive effect of services trade on the environment. The technique channel, therefore, provides a strong rationale for viewing services trade as a critical driver in accelerating global progress towards environmental sustainability.

The empirical analysis in Section 0 builds on these observations and employs various econometric techniques to investigate whether and how the data support the existence of a positive effect of services trade on the environment via the technique channel.

Before turning to the empirical analysis, it is important to note that while designing empirical applications to focus on the technique channel is a valuable first step, this does not imply that the composition and scale channels are less significant or can be overlooked.⁹ The environmental effects of services trade through the scale and composition channels can be particularly relevant when the specific activities involved have a substantial environmental footprint, such as trade in transport services or digital services trade (Box 2). Investigating the empirical role of the scale and composition channels in the relationship between services trade and environmental sustainability remains a crucial objective for future research.

⁹ In their seminal work estimating the net effect of trade on sulphur dioxide (SO₂) concentrations while accounting simultaneously for scale, composition and technique impact channels, Antweiler, Copeland and Taylor (2001_[69]) make two important empirical findings. First, the composition channel explains only relatively small changes in the pollution concentrations. Second, lower pollution from the technique channel more than offsets the higher pollution resulting from a trade-induced increase in the scale of output. These results provide additional motivation to adopt an empirical focus on the technique channel in the present paper.

Box 2. The environmental challenges of trade in transport services and digital services

Transport services trade

Transportation serves as the backbone of international trade, connecting markets and enabling the flow of goods across the globe. However, it contributes significantly to greenhouse gas (GHG) emissions (Cristea et al., 2013^[30]). The environmental impact varies depending on the mode of transportation, highlighting the complexities of balancing trade and sustainability.

Aviation is the most carbon-intensive mode of transport and in 2023 accounted for 2.5% of global energy-related CO₂ emissions (IEA, 2023^[31]), having grown faster in recent decades than rail, road or shipping. International shipping contributes to roughly 3% of global emissions (IMO, 2020^[32]), whereas international road freight transport is estimated to account for 5.5% of global GHG emissions (MIT Climate, 2023^[33]).

Expanding trade in transport services will intensify environmental pressures by increasing overall transport activity and shifting resources away from less polluting sectors. As such, decarbonising transport is essential. Technological advances—such as improved airframes and engines, sustainable aviation fuels, electrification, and greater use of renewable energy and energy-efficient goods—could accelerate this transition. On the policy front, enhancing regulatory transparency, including clear energy efficiency requirements, could improve sectoral efficiency and bolster the credibility of decarbonisation commitments (WTO, 2022^[34]).

Digital services trade

Digitalization is expected to have transformative effects on the economy, including through the production, use and disposal of hardware such as information and communication technologies (ICT) equipment, data centres, data transmission networks and software. The provision of digital services accompanied by digital “volumes” (i.e. devices, network traffic, computing instances and stored data) are growing exponentially (Itten et al., 2020^[35]), but they as well as digital technologies may help to alleviate pressures on the environment. For instance, ICT equipment can help monitor biodiversity and ecosystems.

However, digital services as an economic activity can negatively impact environmental sustainability throughout its life cycle. The mining and extraction of raw materials (e.g. cobalt, palladium) and the production of microelectronic components, especially integrated circuits, used in cloud services and data centres during use phases of digital services are significant contributors to fossil and abiotic resource depletion, as well as to global warming (Itten et al., 2020^[35]).

In addition to energy consumption and greenhouse gas emissions, digital services have other environmental impacts. For instance, the environmental effects of power generation may extend to biodiversity by impacting, for example, on underwater species resulting from underwater data transmission (Liu et al., 2019^[36]).

3 Services trade and the environment: Empirical analysis

The conceptual framework outlined in Section 2 highlights that a comprehensive empirical assessment of the effects of services trade on the environment requires a multifaceted and diverse body of empirical evidence.¹⁰ The strong interest across trade policy fora in leveraging services trade as a tool to achieve environmental objectives creates momentum for advancing this research agenda. The empirical analysis presented here supports this effort.

It exploits the assumption that services trade could have a positive impact on the environment through the technique channel and offers new empirical evidence to test this hypothesis.

This section makes two contributions. First, by running country-time-level panel regressions that control for variation likely driven by the scale and composition channels (as well as by the technique channel activated by trade in goods), the analysis estimates a broad set of empirical correlations between services imports (and regulatory barriers to services imports) and environmental performance across OECD Members and accession candidates. Indicators of environmental performance include both measures of green innovation as well as other quantitative environmental outcomes. This exercise systematically accounts for the heterogeneity of services activities and various dimensions of environmental sustainability. However, while the estimated correlations provide preliminary empirical support for the hypothesised positive role of the technique channel in the overall effect of services trade on the environment, they lack robustness and cannot substantiate causal claims.

The second contribution arises from a more robust empirical framework that introduces a sectoral dimension in the analysis, beyond country-year variations and focuses on emissions as an environmental outcome. By using input-output data to capture the role of services as intermediate inputs in downstream production processes, the analysis directly tests the existence of a technique channel along supply chains. It provides robust estimates showing a technique-driven positive effect of greater services trade openness on CO₂ emission intensity of manufacturing sectors that use services as intermediate inputs.

3.1. Cross-country evidence of the technique channel

As discussed in Section 2, the technique channel within the overall impact of services trade on the environment rests on the assumption that higher access to services from international markets can contribute to innovation for environmental solutions. Do the data support this hypothesis? Are higher services imports or, alternatively, lower barriers to services imports at the country level positively correlated with more inventions to mitigate and adapt to climate change, support the circular economy, and protect biodiversity? Are estimated correlations between services imports (or barriers to services imports) and country-level outcomes across these three dimensions of environmental sustainability consistent with the existence of a positive technique channel?

¹⁰ Simultaneously and precisely estimating all three impact channels and the resulting net effect of services trade on environmental sustainability is a challenging task. Conducting such an analysis is likely to require a focus on a specific metric of environmental sustainability performance (e.g. emissions), thereby limiting the external validity of the results. Moreover, comprehensively assessing the composition channel is particularly difficult because different mechanisms can operate at different levels of analysis. For example, while trade-induced changes in the composition of national output can favour sectors with higher environmental footprint at a macro level, trade can also produce opposite effects at a micro level by promoting the expansion of the greenest firms within sectors.

To answer these questions, a large set of regression equations at the country-year level are estimated covering OECD Members and accession candidates over the period 2005-2021. Several explained (or dependent) variables are used in this regression analysis. First, dependent variables include indicators of environmentally related innovation that are grouped into three main categories.¹¹ The first category consists of indicators related to climate change adaptation and mitigation. These are: the number of inventions patented in a country at a specific year for climate change mitigation technologies; for renewable energy generation; and for climate change adaptation technologies. The second category features indicators on the promotion of the circular economy, including: the number of inventions for recycling or material recovery technologies; for waste management technologies; and for incineration or energy recovery technologies. Finally, the third category includes measures of environment-related innovation with linkages to biodiversity protection: the number of inventions for water resources management technologies; for water pollution abatement technologies; and for wastewater treatment technologies.

Other selected indicators of environmental outcomes across these three categories are also included as dependent variables in the regression analysis. Outcome indicators include: a measure of energy productivity (in the climate change category); the share of municipal waste recycled or composted over total treated waste (for circular economy); and the red list index, an aggregate indicator of species extinction risk (for biodiversity). Finally, the analysis also uses several indicators of pollution (CO₂ and greenhouse gases (GHG) emission intensity) which are relevant outcome variables across all three dimensions of environmental sustainability.¹²

The key explanatory variables or regressors of interest are taken from two distinct set of variables: services import flows and policy restrictions to the importation of services, both measured at the level of the importing country over time and available for several services sectors. Services imports come from the third edition of the OECD-WTO Balanced Trade in Services dataset (BaTIS)¹³ and covers 202 countries and 12 services sectors over the period 2005-21 (OECD, 2025_[37]). Measures of services trade policies are taken from the OECD Services Trade Restrictiveness Index (STRI) database, which covers 51 countries and 22 sectors over the period 2014-24. One regression equation is estimated for each combination of dependent variable (i.e. innovation indicators and other quantitative environmental outcomes across the

¹¹ The indicators of green innovation used here focus on invention rather than technology diffusion and adoption.

¹² All these environmental indicators are listed and described in Table A B.2, which also specifies, for each indicator, whether some OECD Members or accession candidates are not covered in the estimation sample due to limitations in data availability, as well as the source of the data. Indicators on inventions come from the OECD Patent data. Emission intensity indicators are sourced from the OECD Air and GHG emissions database while other environmental outcomes indicators are mostly taken from the OECD Green Growth Indicators database (OECD, 2024_[87]). For more information on the OECD Green Growth Indicators Database see OECD Green Growth indicators, and <https://stats.oecd.org/wbos/fileview2.aspx?IDFile=0eddc076-a4f9-4a2b-8e86-4190c8523b59>.

¹³ BaTIS constitutes the international benchmark for analytical estimates of balanced services trade flows, where non-reported values are estimated using mirroring, gravity estimates, as well as backcasting, nowcasting and interpolation techniques. Trade flows are then adjusted to ensure internal consistency (OECD, 2025_[93]). The services trade flows recorded in BaTIS are constructed within the balance of payments statistical framework, where services components primarily reflect different combinations of cross-border supply (mode 1), consumption abroad (mode 2), and the presence of natural persons (mode 4). In rare cases, balance of payments data may also capture services traded through the establishment of a commercial presence in the importing country (mode 3), a mode of international services supply that is typically covered under the Foreign Affiliates Trade in Services (FATS) statistical framework. For instance, a commercial presence is not considered resident in the host (importing) country if it is established for less than one year, and its sales are therefore recorded as transactions in the balance of payments. This situation is particularly relevant for, and mostly limited to, trade in construction services (UN; IMF; OECD; Eurostat; UNCTAD; UNWTO; WTO, 2012_[38]).

three dimensions of environmental sustainability listed above plus the emission intensity indicators) and regressor of interest (i.e. sectoral services imports and STRI indicators).¹⁴

Given the hypothesised positive effect of services trade on environmental sustainability operating through the technique channel, more services imports and, alternatively, lower policy barriers to services imports are expected to be positively associated with higher environmental performance (both in terms of green innovation and other environmental outcomes), conditional on the trade impacts exerted through the scale and composition channels, as well as via the technique channel activated by goods trade.

To make the estimations in this section capturing an empirical relationship that is as consistent as possible with the technique channel in the environmental impact of services trade, all regression equations partial out the trade impacts exerted through the scale and composition channels, as well as via the technique channel activated by goods trade. In particular, all specifications control for the scale channel through a regressor capturing the size of the economy as measured by gross domestic product (GDP). The composition channel is controlled for by the share of manufacturing in GDP, measuring the composition of an economy between manufacturing and services. Finally, inward FDI flow (USD millions in current prices), a standard measure of the technique channel used in empirical specifications for trade in goods, is added as a control to capture technological gains that come from more FDI in manufacturing sectors and could affect the environmental performance.¹⁵

In each regression, the main explanatory variable (either imports flows or STRI) is lagged by one year to allow for a minimum time gap for the effect of services trade flows or policies on environmental performance. Finally, all regressions control for year-specific shocks which are common to all countries through the addition of year fixed effects. Country fixed effects instead are not included in the baseline specification. Their addition would leave little variation for identification of the coefficients of interest due to limited variability of many indicators over time. Similarly, baseline specifications do not control for economic development at the country-year level. Two reasons motivate this choice: first, the estimation sample is relatively homogeneous in terms of economic development; second, variation in economic development is a relevant factor behind the technique channel that would be important to preserve for identification.¹⁶

Since the analysis relies mainly on cross-country variation for identification, the estimated coefficients can be interpreted as indicative of the direction of the empirical relationship between the variables of interest, rather than as a precise measure of a causal effect. More details on the empirical strategy are provided in Annex B.

3.1.1. Trade in services and environmental sustainability

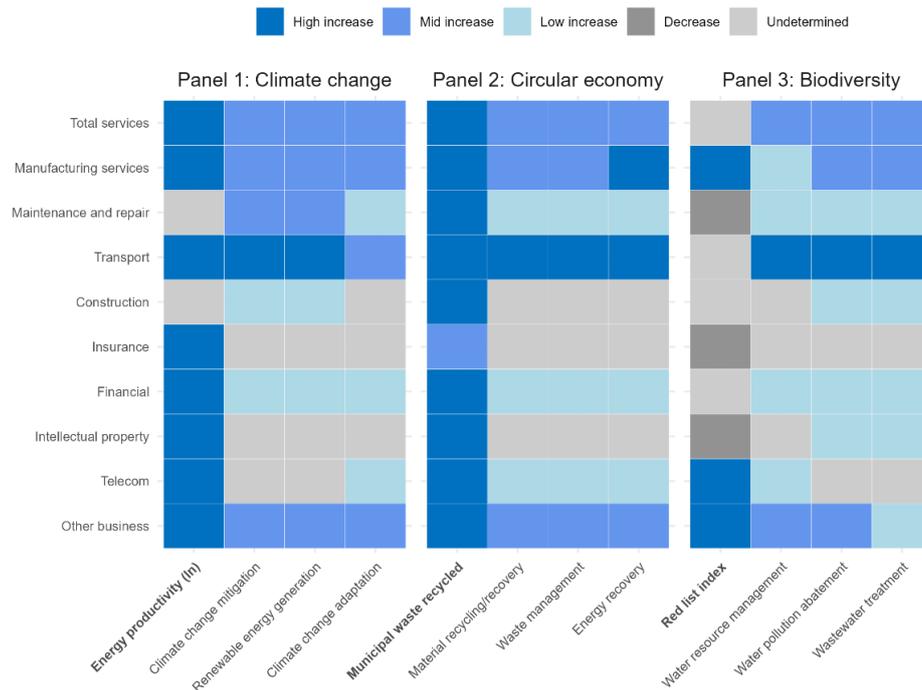
The first set of estimations results speak to the relationship between services imports and environmental innovation as well as other quantitative environmental outcomes. Figure 3 presents the findings grouped according to the three clusters of environmental sustainability performance: climate change adaptation and mitigation; circular economy; and protection of the biodiversity.

¹⁴ Regressions featuring services imports flows on the right-hand side cover up to 46 countries among OECD Members and accession candidates. Regressions with STRI indicators as explanatory variables instead cover 42 countries as the STRI is currently not yet available for the following accession candidates: Argentina, Bulgaria, Romania, and Croatia. See Table A B.1 for the list of countries. Regressions incorporating services import flows cover a maximum period from 2005 to 2021, while those including the STRI are limited to 2014–2021 due to the temporal scope of both the STRI and the environmental performance indicators. Additionally, some years may be excluded from the sample for specific countries due to limited availability of environmental performance indicators.

¹⁵ The choice of control variables follows, among others, Aller, Ductor, & Herrerias (2015_[72]).

¹⁶ Both country-fixed effects and measures of economic development are included in a second set of regressions estimated to explore robustness of the baseline findings. This robustness test is discussed below in Section 3.1.3.

Figure 3. Services trade and environmental performance indicators



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and environmental performance, the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: BaTIS database, Green growth indicators, Patents technology dataset, Our World in Data.

Results are summarised graphically by means of heatmaps. Each cell indicates a specific combination between an indicator of environmental performance taken as dependent variable (listed on the column dimension of the matrix, with quantitative environmental outcomes highlighted in bold, as opposed to indicators of green innovation) and a sectoral measure of services imports used as key regressor of interest (listed on the row dimension of the matrix). Cells are colour coded to reflect whether the estimated coefficient corresponding to each cell reveals that higher services imports are associated with increased or decreased sustainability performance. If the relevant estimate is not statistically significant the relationship between services imports and environmental performance is labelled as undetermined. When a positive relationship is estimated between services imports and environmental performance, the heatmap

further differentiates between high, medium, and low increase in environmental performance associated with higher services imports.¹⁷

Results indicate that increased total services imports tend to be linked to higher environmental performance. This is reflected in the positive, statistically significant, and relatively strong estimated relationship between total services imports and all indicators of green innovation across the three clusters of climate change, circular economy, and biodiversity. Similarly positive, strong associations are estimated between total services imports and the environmental outcome indicator in the climate change cluster (energy productivity), as well as in the circular economy cluster (the share of municipal waste recycled). Only the estimated relationship with the outcome indicator chosen for the biodiversity cluster does not appear to be statistically significant.

However, when examining different types of services, estimated relationships are more heterogeneous. Countries importing more transport, manufacturing related, and other business services, are associated with stronger environmental innovation and other outcomes, consistently across dimensions of environmental sustainability. The sectoral category of other business services includes three main clusters of activities: (a) research and development services (e.g. provision of customised and non-customised research and development services; sale of proprietary rights, patents, copyrights arising from research and development, industrial processes and designs); (b) professional and management consulting services; (c) and technical, trade-related and other business services, including architectural, engineering, scientific and other technical services, but also waste treatment and depollution services (UN; IMF; OECD; Eurostat; UNCTAD; UNWTO; WTO, 2012^[38]). As such, they are associated with basic research, applied research and experimental development of new products and processes, reflecting a direct technique effect of trade in service on the environment.¹⁸

Many concrete mechanisms can be proposed to rationalise and motivate the positive estimated associations between sectoral services imports and environmental performance. Consider as an illustration those suggesting a strong positive relationship between services imports and energy productivity (an indicator of how much economic activity can be generated with a certain amount of energy). Services play a central role in orchestrating the efficient use of inputs in production, and energy is no exception. Imported engineering and R&D services (captured under imports of other business services) can provide access to specialised expertise and advanced technologies that help improve the design of energy-intensive systems, from manufacturing processes to energy distribution infrastructure. Such improvements can reduce energy losses, increase operational efficiency, or facilitate the adoption of less energy-intensive technologies. Additionally, engineering services sourced from international markets may also support firms in optimising the energy performance of production facilities. Exposure to advanced design approaches—such as thermal modelling, innovative materials, or space-efficient layouts—can lead to lower energy use for heating, cooling, or lighting per unit of output.

A wide range of other imported services can also support higher energy productivity by improving coordination, reducing waste, and enabling more efficient decision-making. Management consulting services (also under other business services), for example, can assist firms in streamlining production systems or logistics chains in ways that reduce avoidable energy use. Transport and telecommunications services can enable more responsive supply chains and real-time energy monitoring, both of which help firms adjust

¹⁷ High, medium, and low increases of environmental performance are identified by looking at the magnitude of the estimated coefficient of the main regressor of interest. More precisely, the following approach is adopted: to account for the differing scales of measurement across environmental performance indicators, coefficients are standardised by expressing them in terms of standard deviations. Standardised coefficients above the 66th percentile of all increasing coefficients within each figure are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”.

¹⁸ A more granular analysis of the individual services activities classified under other business services, based on an alternative data source for services imports, is presented in 5Annex B.

operations to minimise energy consumption. Financial and insurance services may also play a role by facilitating the adoption of energy-efficient technologies through improved risk-sharing or access to capital. Energy transport services—such as pipeline transport captured under the transport services aggregate—offer another channel through which services trade may enhance energy productivity. Importing specialised capabilities in this area can help reduce energy losses and improve system performance. For instance, pipeline services can support the efficient delivery of fuels by minimising compression needs and avoiding unnecessary handling.

The discussion of potential mechanisms can be complemented with a quantification of the estimated link between services imports and environmental performance. As an illustration, consider the estimated coefficient in Figure 3 linking energy productivity to imports of other business services, which is equal to 0.049. Since both variables are expressed in logarithmic form in the estimating equation, the coefficient implies that a 1% increase in imports of other business services is associated with a 0.049% increase in energy productivity. To put this into context, the average increase in such imports across the sample is 7%, corresponding to a 0.34% increase in energy productivity—equivalent to approximately 15% of the average annual gain in energy productivity observed in the sample.

Moving to another example, several concrete mechanisms can be put forward to explain the positive association between imports of several services sectors and innovations in the area of technologies for renewable energy. Many renewable energy sectors, including geothermal and ocean energy, depend on specialised services such as engineering, construction, maintenance, and transport to operate efficiently. When these services are sourced from international markets, they open opportunities to collaborate with world-leading firms and experts. These collaborations often go beyond standard service provision: they involve co-designing bespoke solutions to technical challenges, which can generate novel processes or technologies—directly contributing to innovation.

The geothermal energy sector illustrates this well. It relies on a broad range of supporting services, from engineering design and drilling to reservoir management and heavy-duty transport. Engineering services can enable geothermal plants to operate at high-capacity factors, delivering stable and consistent output—unlike more intermittent renewables. Maintenance services ensure long-term productivity by preventing resource depletion. Oversized transport services—sometimes only available through foreign suppliers—allow complex infrastructure like drilling rigs and heat exchangers to be moved in fewer trips, reducing costs and improving efficiency. Similarly, the development of ocean energy technologies depends on collaboration with electrical engineers, construction firms, and underwater maintenance specialists. These partnerships not only enable production but also push the technical frontier, generating spillovers that can lead to new inventions and performance gains across the sector.

Related mechanisms may underpin the observed positive association between services imports and indicators linked to circular economy outcomes, taken as a final example. Services such as transport, manufacturing, maintenance, and engineering play a central role in both mechanical and chemical recycling processes—enabling the transport, cleaning, shredding, and reprocessing of materials like plastics, paper, and metals for reuse. For example, access to large-scale transport equipment can make it possible to move greater volumes of recycled material using the same amount of energy. Likewise, specialised maintenance services can support technical solutions that increase the volume of materials recycled without requiring additional resource inputs.

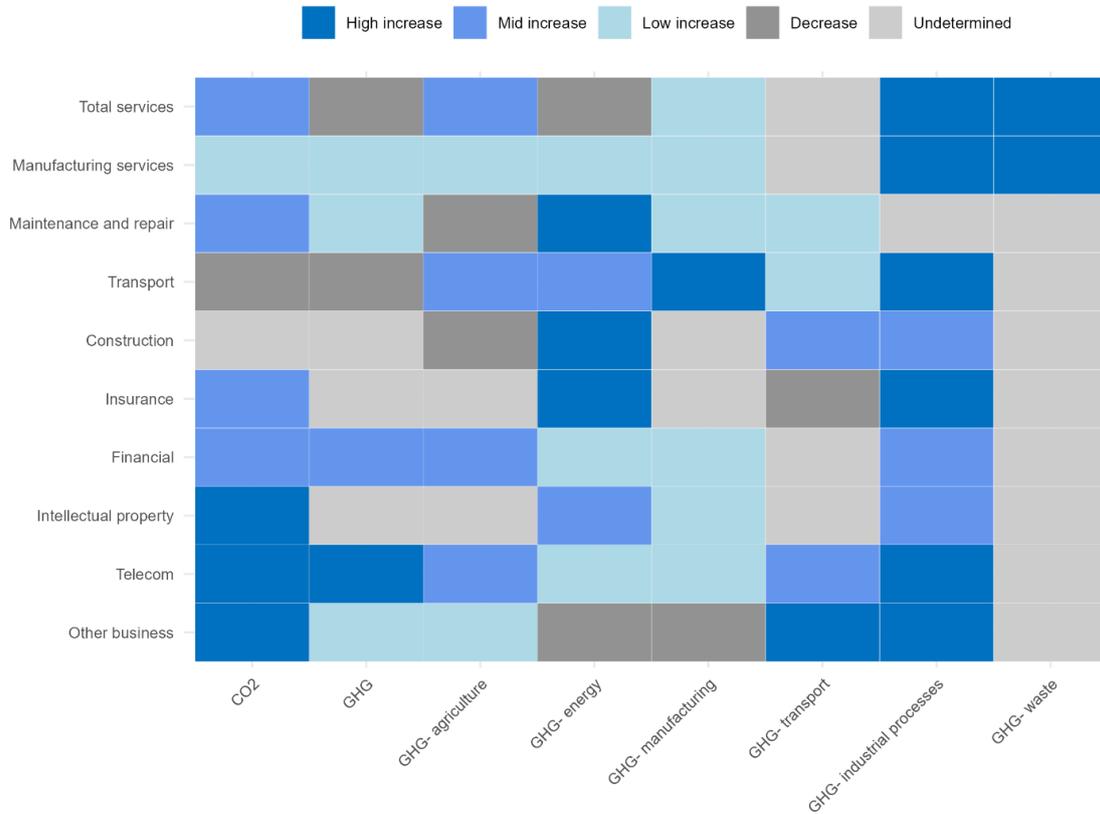
Going back to heterogeneity across sectors, Figure 3 shows that weaker, undetermined or, in few cases, even negative and significant associations with environmental performance indicators are estimated for imports of insurance, construction, and services activities recorded under intellectual property.¹⁹ Finally, maintenance and repair, financial, and telecommunication services are somehow in the middle, with clearly positive patterns but not as pronounced as transport or other business services.

Additional results (Figure 4) show that total services imports are linked to lower emission intensity across several pollution indicators, such as CO₂ emission intensity, GHG emission intensity in agriculture, manufacturing and industrial processes. When looking at the results of Figure 4 per type of services imports, findings indicate that imports of telecom, finance, manufacturing related, and other business services are more strongly and systematically positively correlated to higher sustainability performance, measured by lower pollution intensity. To provide an example, the manufacturing of electrical equipment may require engineering services that could help in production of more energy efficient electrical equipment, while construction and maintenance services can assist with installing renewable energy sources at production facilities.

Additionally, transportation services might be needed to move large equipment using for instance advanced logistics systems that could reduce unnecessary trips by optimizing routes, delivery schedules, and vehicle loads. Similarly, construction services, engineering and telecommunications could help in reducing GHG from transportation through the implementation of more environmentally friendly means of transport. Construction services can create controlled environments to ensure safe battery production for electric vehicles; engineering services can be used in the manufacturing of electric vehicles (EV) and can also assist with innovative ways of using recycled materials (e.g. from lithium-ion batteries) while telecommunication services can allow better data management, and automation across various stages of manufacturing and operation of electric vehicles. For instance, they can help in real-time tracking of EV components and raw materials from suppliers to factories, automate stock management, reducing delays in production, ensuring quality control faster thus saving energy. Similarly, R&D services could enable advanced simulations for battery performance, aerodynamics, and EV efficiency.

¹⁹ The relatively weak association between imports of services that imply charges for intellectual property rights and green innovation deserves particular attention. Some of the services activities captured under the sectoral category of intellectual property are among those that are expected to play a positive effect on the environment through the technique channel because of their potential role in developing technical changes: these include for instance outcomes of research and development processes and computer services whose use is associated with a license. The lack of a strong, positive empirical association is likely due to the composition of the category within the database. The sectoral category of intellectual property indeed shows the importation of other types of services which are not necessarily functional to innovation (e.g. the use of intellectual property rights embedded in cinematographic works and sound recordings, and related rights, such as for recording of live performances and for television, cable or satellite broadcasting).

Figure 4. Services trade and emission intensity indicators



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and sustainability performance (which is equivalent to a decrease in emission intensity, which is showcased by a negative coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: BaTIS database, OECD Air and GHG emissions database.

3.1.2. Policy barriers to services imports and environmental sustainability

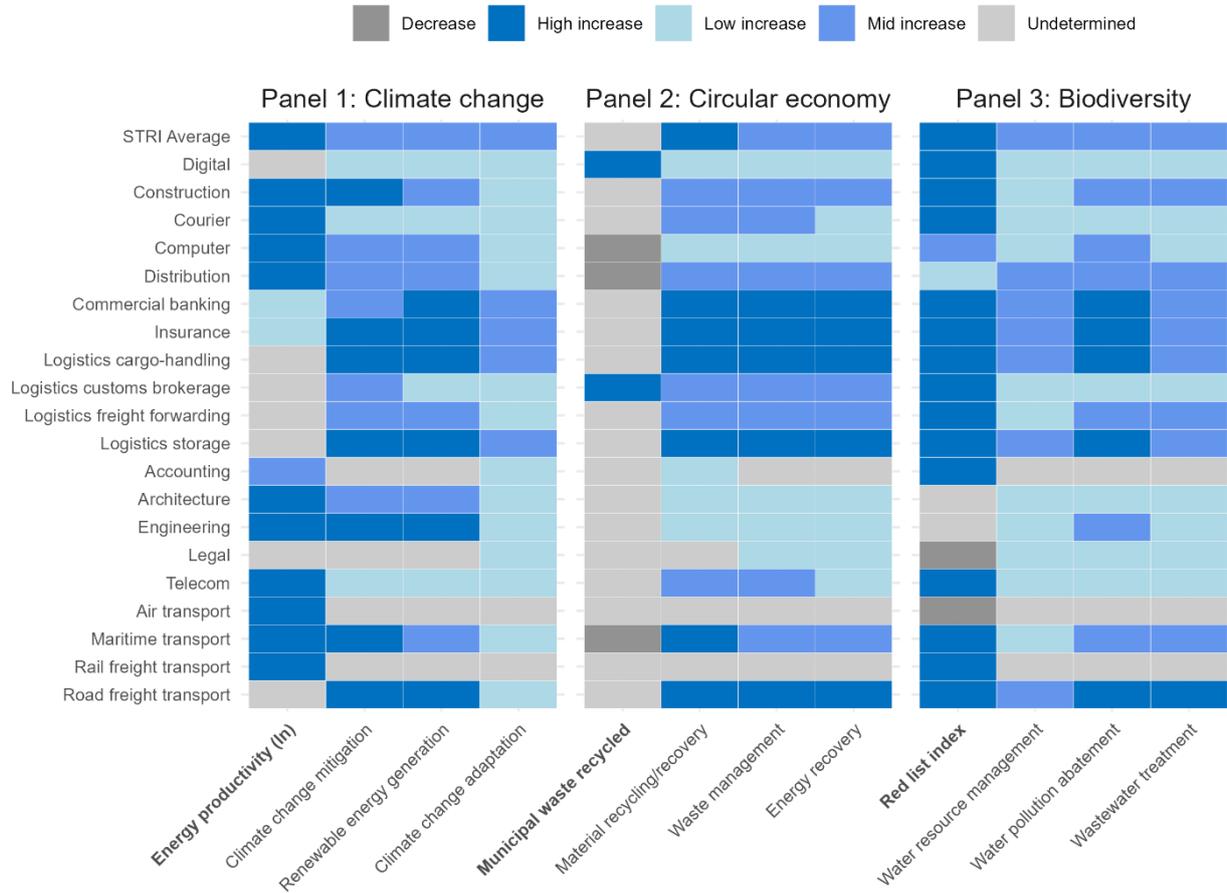
A second set of estimations look at the link between services restrictiveness and environmental sustainability performance.²⁰ Results reported in Figure 5 generally show that a lower average restrictiveness to services imports across sectors, as captured by lower values of the average of STRI sectoral indicators, is associated to higher environmental performance. This pattern is estimated for all indicators of green innovation across the three clusters corresponding to climate change, circular economy, and biodiversity; as well as for two outcome indicators out of three: energy productivity, under the climate change cluster, and the Red list index, for biodiversity.

The sectors where lower policy restrictions seem to be more strongly correlated with environmental performance for climate change mitigation and adaptation include construction, computer services, distribution, commercial banking, insurance, architecture, engineering, and maritime transport services (Figure 5, Panel 1). Lower barriers to digital services and logistics services imports are strongly and consistently associated with higher green innovations for circular economy as well as with the related outcome indicator capturing the share of recycled waste over total treated waste (Figure 5, Panel 2). Environmental performance indicators under the biodiversity cluster seem particularly strongly correlated with lower barriers to services trade across the board (Figure 5, Panel 3).

The weakest patterns of correlation between policy restrictions to trade and green innovation appear instead for accounting, legal, air transport, and rail freight transport services. However, there is no services sector where the data suggest a robust negative correlation between a more open trade policy regime and environmental performance.

²⁰ The services sectors covered by these estimates do not exactly match those reported in Figures 3 and 4, as the OECD STRI database—used as the source for services trade restrictiveness—employs a different sectoral classification from that of the OECD-WTO BaTIS database (for a detailed list of the services activities covered under each sectoral STRI indicator, as well as their correspondence with the sectoral categories defined in the balance of payments statistical framework used by BaTIS, readers may refer to the OECD sector papers available at <https://www.oecd.org/en/topics/sub-issues/services-trade-restrictiveness-index.html>). Moreover, even when there is strong overlap in sectoral coverage between the two datasets, the estimated relationship with the environmental sustainability performance indicator may still differ. This is primarily because the STRI sectoral indicators also aggregate policy measures that tend to affect mode 3 imports more strongly—flows that are largely absent from the OECD-WTO BaTIS database. Other differences may stem from the timing of trade flow adjustments to policy changes. Benz et al. (2023^[39]) show that the full impact of services trade reforms on imports typically materialises over the long term. As a result, services trade policy may display a different empirical relationship with environmental sustainability than observed trade flows shaped by the same policy. Finally, services trade restrictiveness is only one of many factors influencing trade flows, which may also contribute to differing patterns of correlation with environmental sustainability performance.

Figure 5. Services restrictiveness and environmental performance indicators

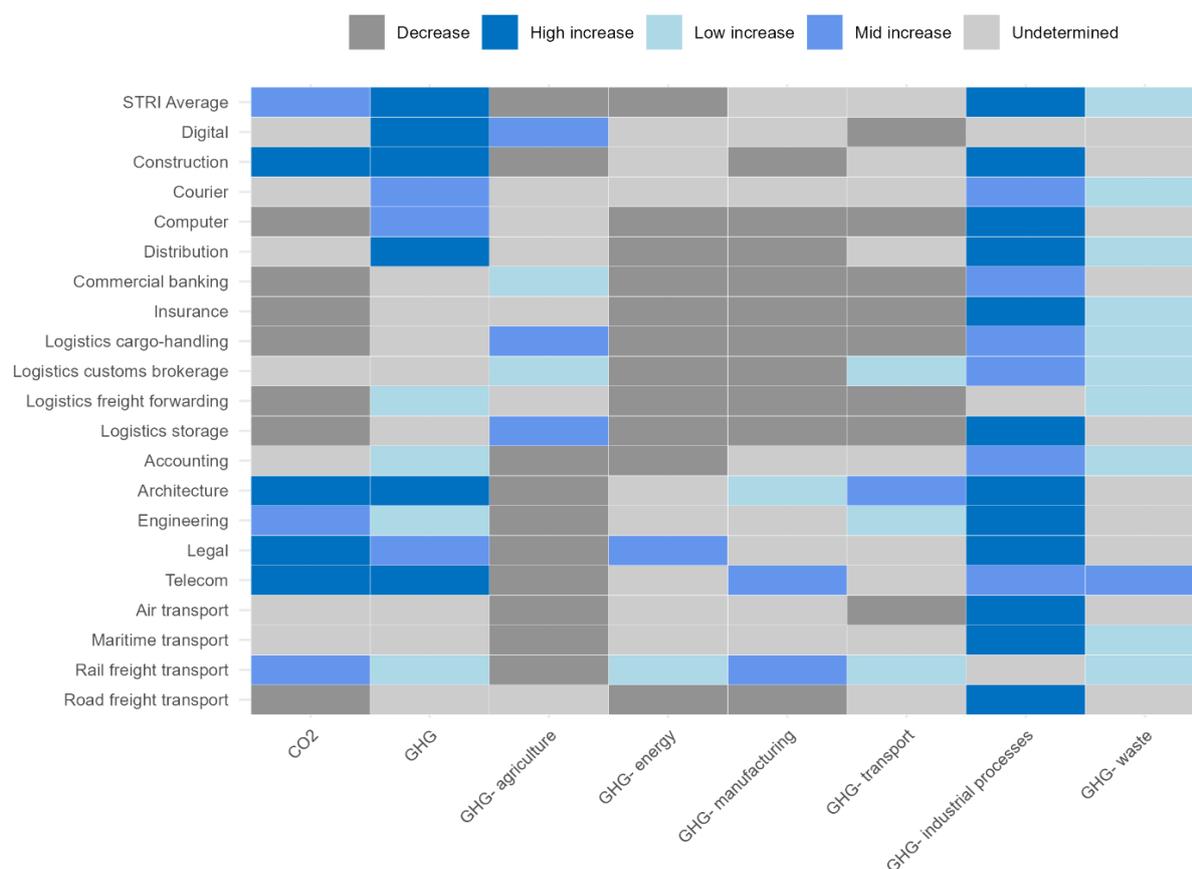


Note: This figure visually presents the estimated coefficients capturing the relationship between different categories of the STRI (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services restrictiveness reduction and environmental performance (which is showcased by a negative coefficient, as services trade liberalisation is associated with a reduction in the STRI), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: OECD STRI database, Green growth indicators, Patents technology dataset, Our World in Data.

Turning to indicators of emission intensity (pollution), the data presents a more nuanced picture. Figure 6 indicates that lower policy restrictions on services imports are not consistently linked to lower pollution. While the positive relationship between services trade restrictiveness and emission intensity (i.e. lower restrictions correlating with lower emission intensity) is strongly supported by estimates for GHG emissions in industrial processes, and waste, this relationship is weaker—or even reversed—for agriculture, energy, manufacturing, and transport. This is particularly evident in the case of restrictions on imports of computer, commercial banking, insurance, and logistics services.

Figure 6. Services restrictiveness and emission intensity indicators



Note: This figure visually presents the estimated coefficients capturing the relationship between different categories of the STRI (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services liberalisation and sustainability performance (which is showcased by a positive coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: OECD STRI database, OECD Air and GHG emissions database.

3.1.3. Discussion and robustness

The cross-country estimates presented above provide first, descriptive empirical evidence supporting the hypothesized positive impact of services trade on environmental performance through the technique channel across OECD Members and accession candidates. The findings show a degree of heterogeneity across services sectors and dimensions of environmental sustainability. For instance, key services activities such as research and development, professional and management consulting services, technical and scientific services (such as architecture and engineering), and core environmental services (all grouped under “other business services” in trade data) appear more strongly associated with advancements in innovations and other outcomes related to climate change, the circular economy, and biodiversity protection.

Among the most supportive estimates are those indicating that higher services imports are strongly associated with higher energy productivity, higher shares of recycled waste, and lower GHG emission intensity in industrial processes across countries. Similarly, positive correlations between services imports across nearly all analysed sectors and green innovation indicators suggest a strong technique channel at play. This is particularly evident for innovations related to climate change mitigation technologies, renewable energy generation, energy recovery, and water pollution abatement.

A similar pattern emerges when examining services trade policy. Lower regulatory restrictions on services trade are empirically associated with better environmental performance, particularly for architecture, engineering, and telecommunications services. This relationship holds across various environmental indicators, including pollution intensity measures. Among these, GHG emission intensity in industrial processes shows the strongest positive correlation with open services trade policies and environmental sustainability performance.

Despite these consistent patterns, several important caveats warrant caution in interpreting the findings. First, the services trade restrictiveness indicators used in the analysis capture policy measures relevant across all modes of services provision, but the trade data do not include services imports through commercial presence (mode 3). Second, to maximize the data's variation and identify the technique channel's role in the relationship between services trade and environmental sustainability, the regression model incorporates only a minimal set of control variables—those required to account for the scale, composition, and goods trade-driven technique channels—plus year fixed effects. Consequently, the model does not account for potentially confounding factors, introducing a risk of omitted variable bias.

Several robustness exercises address these concerns. First, all estimations underlying Figure 3 and Figure 4 are replicated using a measure of total services imports that includes mode 3 data, sourced from the WTO Trade in Services by Mode of Provision (TISMOS) Database. Results reported in Figure A B.1 and Figure A B.2 of Annex B broadly align with the initial patterns. The more granular sectoral classification in TISMOS also allows for a detailed examination of the “other business services” category, suggesting that the positive correlation with environmental sustainability performance is primarily driven by research and development and professional consulting services in relation to green innovation, while architecture and engineering services are more relevant for correlations with emission intensity indicators.

As a second robustness exercise, the baseline regression model is augmented with GDP per capita (to capture economic development), GDP per capita squared (to control for the environmental Kuznets curve²¹), and country fixed effects (to isolate time-invariant country-specific characteristics). This approach reduces confounding variation and enables cleaner identification, minimizing the risk that correlations reflect mechanisms unrelated to the technique channel. However, this most stringent specification introduces the risk of neglecting important variation generated by the existence of the technique channel. Moreover, it reduces degrees of freedom, leading to higher standard errors and making it harder to detect statistically significant relationships. Most estimates lose statistical significance, and the sparse significant results do not indicate any consistent patterns (see Figure A B.3-Figure A B.8 of Annex B). Importantly, none of these estimates suggest a negative impact of services trade on the environment through the technique channel.

Overall, this systematic loss of statistical significance under more demanding specifications highlights the limitations of deriving conclusive evidence for the technique channel's effects using country-year-level data. The findings should not be interpreted as causal claims about the impact of services trade on environmental sustainability via the technique channel. Instead, they offer a broad set of *prima facie* associations that descriptively support the hypothesized positive role of services trade. These associations,

²¹ The Environmental Kuznets curve literature suggests a non-linear relationship between pollution and wealth (Grossman and Krueger, 1995^[73]), finding that after a certain wealth level has been achieved, pollution levels begin to decline.

even under more stringent specifications, do not contradict the existence of a strong technique channel. Further empirical research—beyond the constraints of country-year-level variation—is necessary to provide more robust evidence. The next section’s empirical exercise aims to address these limitations and advance this line of inquiry.

3.2. The technique channel along manufacturing supply chains

Manufacturing is a major contributor to global CO₂ emissions and reducing its environmental footprint is a crucial challenge in the process of mitigating climate change. Improved access to services inputs from international markets, resulting in lower prices and/or greater input variety, is shown to be a relevant channel of productivity increases in the manufacturing sector (Benz et al., 2023^[39]). This section aims at investigating whether lower policy restrictions to access foreign service inputs play an equally critical role in enhancing the environmental performance of manufacturing sectors downstream in the supply chain.²²

As argued in Section 2, services trade (imports), through the technique channel, can trigger and support technical changes leading to greener production techniques in manufacturing sectors that use services as intermediate inputs. In this section, the existence of a technique impact channel along supply chains is tested by estimating the effect of restrictive service trade policies on environmental performance in downstream manufacturing industries. The outcome variable in the estimating equation consists in the CO₂ emissions intensity in production, measured as emissions over gross output at the country i , year t , and downstream manufacturing sector j level. The treatment variable (or the main explanatory variable) instead is an indicator of trade restrictiveness imposed by country i affecting the importation of services sectors upstream in the supply chain of each manufacturing sector j . It is computed as an input-intensity weighted measure of services trade restrictiveness. To minimise the risk that services trade policy is endogenously determined by services input use, these weights are kept constant over time and across countries, reflecting services input use of a reference country, the US, in a pre-sample reference year.

Contrary to the cross-country panel regression framework employed to estimate linkages between services trade (and services trade policy) and environmental performance in Section 3.1, the addition of a sectoral dimension in the empirical setting described here provides significantly more statistical power that allows to adopt a demanding identification strategy and propose a causal interpretation of the estimation results. The strategy to identify the causal effect of upstream services trade policy on the environmental performance of downstream manufacturing sectors is based on a comprehensive battery of fixed effects that aim to control for any observable and unobservable confounding variation at the country-time, sector-time, and country-sector level. This, together with the inclusion of key controls varying at the country-sector-time level, provide a robust solution to the main risks of endogeneity.²³

The main data sources used to build the estimation sample include: the OECD TECO₂ database for emission intensity in production; the TiVA database for measures of services input intensity; the OECD STRI database for services trade policy.²⁴ After combining all sources, the final estimation sample covers

²² Beyond the existing body of evidence on the effects of services trade openness on economic performance downstream in the supply chain, this exercise also relates to the literature examining the impact of goods imports on the pollution intensity of firms that use these goods as intermediate inputs in their production processes. In a contribution to that workstream Akerman, Forslid and Prane (2024^[94]) show that, within a sample of Swedish firms, increasing imports of intermediate goods significantly reduce carbon intensity at the firm level.

²³ Controls added to the baseline estimation equation include: the applied tariff in country i in sector j in year t ; an indicator of tariff restrictions applying to the manufacturing inputs of sector j in country i and year t ; a measure of (labour) productivity in sector j , country i and year t ; the share of gross exports (imports) of manufacturing sector j in total manufacturing exports (imports) of country i at time t .

²⁴ STRI measures of services trade policy are matched with TiVA data on services input intensity by the sectoral categories, producing a common list of 13 services sectors which are used to build the composite indicator of upstream

49 countries and 17 manufacturing industries over the period 2014-2018. Further details on the empirical strategy, identification, and data are given in Annex C.

Estimation results strongly indicate that lower policy barriers to imports of services used as intermediate inputs reduce CO₂ emission intensity of manufacturing sectors downstream in the supply chain (detailed regression results are reported in Table A C.4). By interpreting the results as causal estimates, a quantification exercise can be conducted to assess the magnitude of the impact of specific services trade reforms on the emission intensity of manufacturing sectors across countries.

The key ingredients of the quantification exercise proposed here are the changes in the treatment variable that reflect meaningful, realistic, and comparable reform scenarios in services trade policy. These changes are computed starting from changes in the STRI. The OECD STRI data used to measure services trade policy restrictiveness consist of sectoral indicators varying from 0 to 1, with 0 (1) capturing minimum (maximum) restrictiveness. Therefore, a negative (positive) change in an STRI indicator reflects a policy reform that removes (adds) policy barriers to services trade.

To identify reform scenarios as measured by changes in STRI indicators, the 25th percentile of the distribution of yearly percentage changes in terms of services trade liberalisation observed across countries within each services sector between 2014 and 2018 is taken as a baseline. For each services sector, the 25th percentile is a negative number, thus representing a liberalising reform, whose ambition has been met or exceeded by one country every four. For these countries, the actual liberalising reform implemented between 2014 and 2018 is used in the quantification exercise. For the other 75% of countries, the hypothesised scenario assumes a liberalising reform corresponding to the 25th percentile baseline.

In this way, a counterfactual change in the indicator of upstream services trade restrictiveness is computed for each country i and downstream manufacturing sector j , weighting these country-specific sectoral reform scenarios with services input intensity. Finally, the results from the regression framework summarised above are used to estimate the reduction in CO₂ emission intensity associated with these changes in services trade policy. A more formal description of this quantification exercise can be found in Annex C.

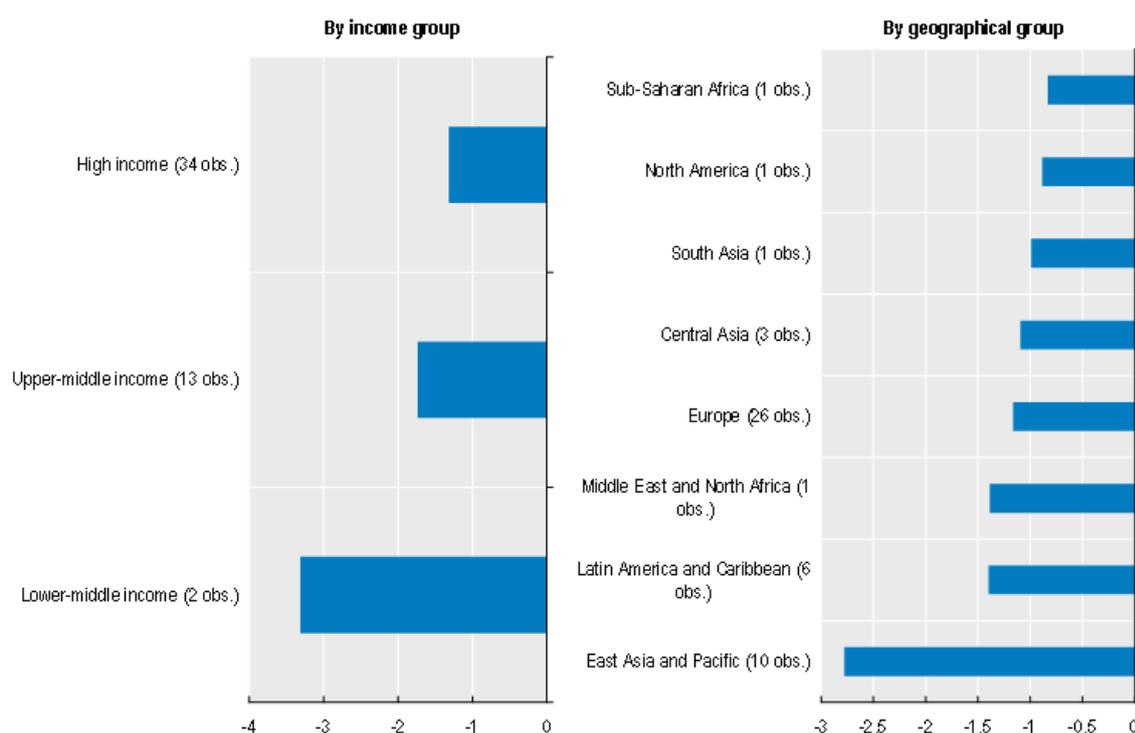
The main outcome of this quantification exercise consists of an estimated impact of services trade reforms on emission intensity for each downstream manufacturing sector in each country, for a total of 833 (17 sectors by 49 countries) estimated impacts. On average, services trade reforms as ambitious as those implemented by the top quartiles of reformers, decrease CO₂ emission intensity by 1.5 percentage points. In countries where these reforms correspond to bigger changes in the STRI, and in manufacturing sector where services inputs are used more intensively, CO₂ emission intensity is estimated to decrease by up to almost 9%. These figures are economically significant. A 1.5% decrease in emission intensity indeed accounts for about one fifth of the total decline in average CO₂ emission intensity across sectors over the period and on average across the countries considered in the analysis.²⁵

services trade restrictiveness at the i - j - t -level. These sectors include: water supply; sewerage, waste management and remediation activities; construction; land transport and transport via pipelines; water transport; air transport; warehousing and support activities for transportation; postal and courier activities; telecommunications; IT and other information services; financial and insurance activities; professional, scientific and technical activities; education. Since no STRI indicator is available for water supply; sewerage, waste management and remediation activities; and education, the value of the computer services STRI is assigned to those three sectors. The methodology for the STRI on computer services includes measures that are likely to apply across the board rather than being highly sector specific, making it a good baseline measure of restrictiveness for any sector.

²⁵ The benchmark considered for comparison is computed taking the average emission intensity for each country across sectors. For each country, the percentage change between the 2015 and the 2018 values of this average is computed. The cross-country average of these changes is a decrease in emission intensity by 7 percentage points. This percentage is about five times as big as the average estimated percentage decrease in emission intensity following the services trade reform used in the quantification exercise of this paper.

Figure 7 aggregates the estimated counterfactual percentage changes in CO2 emissions intensity computed by income group (left panel) and geographical region (right panel).²⁶ The figure suggests that less developing countries, (especially in the East Asia and Pacific region), stand to gain relatively more from services trade liberalisation in terms of downstream manufacturing emission intensity. More granular aggregations at the country level are reported in Annex (Table A C.7).

Figure 7. Quantification results: Average estimated reductions (in percentage changes of CO2 emissions intensity) by income and geographical group



Note: Each bar is the average of estimated percentage changes in CO2 emissions intensity within the respective income (left panel) or geographical group (right panel).

Source: Authors' elaboration.

By construction of the quantification exercise, greater predicted reductions in CO2 emissions intensity tend to be observed in countries with higher initial (2014) average levels of services trade restrictiveness across services sectors as well as in sectors with higher services input intensities. However, further estimations provide additional insights on the linkages between the estimated effects of services trade reforms across supply chains and relevant characteristics at the country or sector level (detailed estimation results are reported in Table A C.8.).

First, the predicted reductions in CO2 emission intensity under the reform scenario are greater in country-sector pairs with higher initial emission intensity levels (measured in 2014). This suggests a pattern of cross-sectoral convergence in downstream manufacturing environmental performance following upstream services sector liberalisation. Moreover, larger predicted reductions are observed in countries with higher initial services trade restrictiveness or lower GDP per capita, indicating that those with greater reform potential or lower development levels stand to benefit more from services trade liberalisation in improving manufacturing environmental performance.

²⁶ Income groups and geographical regions follow the World Bank classification.

Finally, results presented here hold across several robustness checks. These include lagging the treatment variable by one year to address reverse causality concerns; estimating the baseline model with two-way clustered fixed effects by country and sector (Cameron, Gelbach and Miller, 2011^[40]), allows for autocorrelation of the errors within countries and sectors; Monte Carlo simulations with random services intensity weights, to prove that results cannot be driven by randomness in services input intensity; and replicating the baseline estimation by removing each country and sector at a time, to verify that the results are not driven by any particular country or industry. Robustness tests are discussed in detail in Annex C.

Overall, this empirical exercise provides strong and robust evidence that, through the technique channel of the environmental effect of services trade, increasing access to foreign services inputs can be an effective policy strategy to reduce the environmental footprint of manufacturing supply chains. This impact appears particularly strong for more polluting manufacturing sectors and countries with lower per capita GDP.

4 Environmental policy and services trade

The literature on globalisation and the environment identifies environmental policy as a key factor influencing the relationship between trade and environmental sustainability (Copeland, Shapiro and Taylor, 2022^[3]). Most studies in this area have theoretically and empirically examined whether and how stricter environmental standards affect the way trade alters the composition of economic activities. In other words, these studies explore how environmental policy shapes the composition channel of the environmental effect of services trade, for instance, by influencing comparative advantage in clean or polluting industries (Copeland and Taylor, 1994^[41]).

With the empirical focus of this paper on the technique channel, this section introduces environmental policy to derive testable implications regarding its role in shaping the impact of services trade on environmental sustainability via the technique channel.

Environmental policy can drive economic actors to seek international markets for services that are crucial for designing or adopting environmental solutions and implementing technical changes needed to meet more stringent environmental standards. This, in turn, can trigger or amplify the technique channel of services trade's effect on the environment. Additionally, there may be a complementarity between services imports and environmental policy in generating technical changes that lead to more environmentally sustainable economic activities. The same services imports from a foreign supplier can have a greater sustainability impact where stricter environmental regulations create incentives to design the contract for services provision to achieve higher sustainability standards.

However, a positive effect of stricter environmental policy on services imports, and the complementarity between environmental policy and services trade, are not sufficient conditions for a stronger positive technique-driven environmental impact of services trade in policy environments characterised by more stringent environmental standards. Services trade can also substitute for environmental policy in achieving environmental sustainability objectives. Environmental policy stringency is likely to promote mechanisms — beyond those triggered by imported services — to enhance the environmental sustainability of economic activities. For example, domestic investments in research and development or the growth of strategic domestic services sectors. Therefore, countries with higher environmental standards are likely to have a more diverse and robust set of tools to address environmental objectives. In these cases, services trade might have a more significant environmental impact in countries with lower environmental standards, where foreign services are likely one of the few available drivers of technical change.

Overall, the role environmental policy can play in shaping the environmental effect of services trade is complex. On the one hand, environmental policy stringency can increase services imports by creating incentives for economic actors to source higher quality-to-price ratio services from international markets. On the other hand, there can be both complementarity and substitutability between services trade-induced technical change and environmental policy in generating environmental sustainability outcomes. Ultimately, whether the positive technique-driven effect of services trade on the environment is stronger under stricter environmental policies is an empirical question.

The remainder of this section brings these hypotheses to the data and investigates: (a) to what extent more stringent environmental regulations create incentives for economic actors to disproportionately rely on international markets rather than domestic suppliers for services required to meet higher sustainability standards; and (b) whether and how the technique-driven linkages between services trade and environmental sustainability change with higher levels of environmental policy stringency. In doing so, the empirical analysis accounts for heterogeneity across dimensions of environmental policy, services sectors, and environmental sustainability objectives.

The measures of environmental policy stringency used in these exercises come from the OECD Climate Actions and Policies Measurement Framework (CAPMF) database (Nachtigall et al., 2022^[42]). The CAPMF project collects data on 130 individual policy measures across 50 countries over the 1990-2022 period. Building on information at the level of individual policy measures, CAPMF environmental policy stringency indicators are constructed following different levels of aggregation. The empirical analysis presented below employs both the most aggregate country-level indicator and 11 indicators that aggregate individual policy measures by policy type.²⁷ These indicators cover market-based instruments (such as taxes and fees, trading systems, and subsidies), non-market-based policies (including performance standards, technology standards, information instruments, and a residual category of other non-market-based instruments such as, for instance, speed limits on motorways, as well as methane abatement policies); and other policy types (environmental targets, policies pertaining to international co-ordination, climate governance, and climate data). The 11 CAPMF policy-type indicators, with examples of individual measures included under each, are listed in Table A D.1²⁸

4.1. Does environmental policy promote the use of international services?

Trade can play an important role in providing domestic economic actors with access to services available on international markets that are likely to enable and support the transition to more environmentally friendly processes and performance (Section 0). This section explores empirically whether and how environmental policy promotes the use of services sourced from international markets, or, in other words, whether and how environmental policy affects services imports.

Environmental policies can create incentives for economic actors to find efficient and effective solutions for complying with more ambitious environmental standards, including using services required to design, implement and disseminate environmentally sustainable economic practices. If those services tend to be available in more varieties, at cheaper prices, or higher quality on international markets compared to domestic suppliers, then, all else being equal, more stringent environmental policies could lead affected economic actors to rely more on services imports than on supply from domestic sectors. The propensity to import services rather than sourcing them from domestic markets can also increase when exporting

²⁷ This aggregation by policy type is one of the approaches built in the CAPMF database. Alternative aggregations are available. For more details are available on the CAPMF data webpage: [OECD Data Explorer • Climate actions and policies measurement framework](#).

²⁸ More details are available on the CAPMF data webpage: [OECD Data Explorer • Climate actions and policies measurement framework](#).

countries enforce more stringent environmental policies. Foreign suppliers operating under higher environmental standards can gain a competitive edge in providing services for environmental solutions, making international markets more attractive sources for such services.

This section examines the extent to which data support these mechanisms and how they vary across service sectors and environmental policy dimensions.

4.1.1. Econometric model and preliminary estimations

The hypothesis of a positive differential effect of environmental policy stringency on services imports with respect to domestic sourcing can be tested empirically using a structural gravity framework with domestic trade flows (Heid, Larch and Yotov, 2021^[43]; Benz and Jaax, 2022^[44]; Benz, Jaax and Yotov, 2022^[13]; Beverelli et al., 2024^[45]). To apply this method, a structural gravity equation featuring importer-time, exporter-time, and importer-exporter fixed effects is augmented with an additional term, consisting in the interaction between a measure of environmental policy stringency in the importing country and an international border (IB) dummy. The estimated coefficient of such interaction term is interpreted as the effect of environmental policy on services imports with respect to domestic services trade, defined as total services production minus services exports.²⁹ 0 describes this method in greater detail and reports the main estimating equation used in this exercise.

Environmental policy stringency is measured with the CAPMF indicators introduced above (see details in Table A D.1). The dataset of bilateral services trade with internal flows instead is constructed using both the OECD-WTO BaTIS database combined with the OECD STAN database, and the WTO-UNCTAD-ITPDE database. Beyond an aggregate measure of total services trade, these datasets feature specific sectoral flows for seven services sectors, including maintenance and repair, transport, construction, insurance and pension, financial services, telecommunication, other business services.

As a first step, the differential effect (on international trade with respect to domestic sourcing) of each individual dimension of environmental policy stringency, as captured by the 11 policy-type CAPMF indicators, as well as by the most aggregate, synthetic CAPMF index, is tested separately for total services trade and for each of the seven sectors covered in the trade database.³⁰ All estimations include importer-time, exporter-time and importer-exporter fixed effect and are conducted by applying the Poisson Pseudo Maximum Likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006^[46]) with algorithms to handle high-dimensional fixed effects (Correia, Guimarães and Zylkin, 2020^[47]).³¹ The resulting 96 estimated coefficients of the interaction between environmental policy stringency and the IB dummy depict a first

²⁹ As shown in a similar setting by Beverelli et al. (2024^[45]), this econometric approach does not allow for the separate identification of the differential impact of unilateral environmental policies implemented by the importer and the exporter. While the hypothesised mechanisms lead to the same conclusion—that more stringent environmental standards, whether in the domestic (importing) or foreign (exporting) country, can increase the propensity to import services rather than source them domestically—the discussion of the empirical exercise presented here focuses on the mechanism linking such propensity to environmental policy stringency in the importing country. A more in-depth examination of how environmental policy affects the export competitiveness of services firms remains an important avenue for future research.

³⁰ This leads to estimating eight times 12 gravity equations with internal trade.

³¹ The inclusion of exporter-time and importer-time fixed effects allows to control for multilateral resistance terms and any observable or unobservable country-specific characteristics that may also vary over time (productivity shocks, exchange rate fluctuations, terms of trade changes) (Baier, Yotov and Zylkin, 2019^[65]). Country-pair (or importer-exporter) fixed effects instead allow to control for all time-invariant bilateral explanatory variables normally included in gravity analysis (distance, common language, common border, etc.). Additionally, they address endogeneity of policies depending on bilateral relationships, allowing for a more robust causal interpretation of the coefficients (Baier and Bergstrand, 2007^[66]). Together, these three sets of fixed effects lead to identification of the coefficients of interest only from variation over time and within country pairs.

characterisation of the role of environmental policies as drivers of services trade (the estimated coefficients are reported in Figure A D.1 of 0).

Overall, these estimates confirm the hypothesis of a positive differential effect of higher environmental policy stringency on services imports with respect to the use of domestic services, both across different policy dimensions and services sectors. The magnitude of the estimates suggests economically meaningful effects. Consider, for example, the differential effect of environmental policy stringency in the area of climate governance on total services imports with respect to domestic trade. The estimation results imply that an increase of policy stringency by roughly half of a standard deviation of the CAPMF indicator, leads to a percentage change in total services imports which is 4 percentage points higher than the percentage change in domestic sourcing. In other words, assuming the more stringent policy measures on climate governance would lead to an increase of 1% in services performed by domestic suppliers for domestic demand, then services imports would increase by 5%.³²

Transport services stand out as an exception, with over half of the estimates not being statistically significant, and most of the remaining ones pointing to a negative differential effect of environmental policy. In all other services sectors, over 70% of the coefficients show a positive differential effect. Across policy types, all CAPMF indicators suggest a positive differential effect in most sectors.

4.1.2. Which dimensions of environmental policy are likely to be more relevant?

There is considerable scope to test the robustness of these initial results and to move towards a more sophisticated assessment of the role of environmental policy as a driver of services imports. The main limitation of the findings discussed so far is the assumption that different dimensions of environmental policy stringency impact trade in isolation. This assumption is inherent in the approach of including only one CAPMF indicator (interacted with the IB dummy) in each gravity equation. While identifying the empirical interdependencies between granular dimensions of environmental policies in incentivising the recourse to international services markets is beyond the scope of this paper, a robust empirical analysis of the differential effect of environmental policy on trade should account for the possibility that multiple dimensions of environmental policy stringency may simultaneously influence trade.

The next exercise addresses this challenge by proposing a machine-learning based approach to gravity estimation that allows to identify, among many variables of interest, those that appear with higher predictive power. This method, first introduced by Breinlich et al. (2021_[48]) to single out the most important provisions of deep trade agreements from a trade generating perspective, can be adapted directly to the problem of selecting dimensions of environmental policy stringency in the gravity framework with domestic trade flows illustrated above.

The approach consists of two steps. First, the Lasso (least absolute shrinkage and selection operator) method for variable selection is applied to the PPML-based estimation of the gravity equation with internal trade augmented with all 11 policy-type CAPMF indicators, each of them interacted with the IB dummy. In this application, a regressor-specific penalty is associated to the coefficients of these 11 interaction terms to force some of these coefficients to go to zero and end up with only a subset of the initial interactions. Following Breinlich et al. (2021_[48]), this first lasso estimation is implemented using the ‘plug-in’ approach to determine the tuning parameter as proposed by Belloni et al. (2016_[49]), and is therefore labelled ‘plug-in PPML-lasso’.

Second, each interaction between an environmental policy stringency indicator and the IB dummy surviving the initial regularisation is regressed on those interactions that have not been selected as relevant by the plug-in PPML-lasso. Breinlich et al. (2021_[48]) call this second step ‘iceberg lasso’. Its purpose is indeed to

³² See 0 for a more detailed discussion of the estimation results and their quantification.

go beyond the initial set of environmental policy indicators chosen for the optimal properties of their interaction with an IB dummy as predictor of international and domestic trade flows.

For an analysis that aims to shed light on the most important dimensions of environmental policy as causal determinants of services imports patterns, the set of indicators identified by the plug-in PPML-lasso might be just the tip of the iceberg. The lasso solution to the variable selection model in fact tends to pick only one “winner” among those variables that play a similar predictive role. Therefore, among the interactions between environmental policy indicators and the international border dummy excluded for their collinearity with the selected ones, there might be other good candidates for exerting a causal effect on services trade. The iceberg lasso is introduced precisely to identify those potentially relevant causal factors missed by the plug-in PPML-lasso.

Taken together, the environmental policy indicators appearing in the interactions selected by the plug-in PPML-lasso first, and by the iceberg lasso in the second stage, constitute a group of variables that is likely to include the dimensions of environmental policy stringency most relevant to predict the differential changes in services imports with respect to domestic trade. 0 reports estimation results from each of these two steps and Figure A D.2 summarises graphically which CAPMF indicators are identified as relevant across sectoral categories of services trade.

Overall, the results suggest that almost all 11 policy-type CAPMF indicators can exert a differential effect on services imports across most of sectoral categories. While the plug-in lasso significantly reduces the number of relevant dimensions of environmental policy stringency in the first step, the iceberg lasso estimations in the second step tend to reintroduce almost all CAPMF indicators in the pool of relevant candidates. In contrast with this pattern, the results strengthen the finding that environmental policy stringency does not have a statistically significant differential effect on imports of transport services, while also pointing towards the same conclusion for insurance and pension services. In fact, for these sectoral categories the plug-in PPML-lasso does not select any interaction term as relevant. Insignificant results for these services sectors could be due to both a methodological limitation and the nature of trade in these sectors. Transport services typically require a local infrastructure, and barriers to entry and competition are quite prominent in most countries. For insurance and pension services, barriers to entry are also very common. This leads to both harder conditions for entry of foreign providers, as well as to most trade happening under mode 3, which is not captured by BaTIS and is partially embedded in measures of internal trade.

Moreover, estimations from the two-step algorithm indicate two types of environmental policies (trading systems and targets) as likely irrelevant factors for the differential effect on imports of construction services.

4.1.3. Towards a robust assessment of the differential effect of environmental policy on services imports

Equipped with an empirical model to identify the differential effect of environmental policy on services imports, and with a list of indicators that is likely to include the dimensions of environmental policy stringency most relevant to the fit of the model, the final step in the analysis could consist in running the internal trade-augmented gravity regressions for services trade including simultaneously all the interactions between the international border dummy and all environmental policy indicators listed as relevant. However, the utilised lasso-based variable-selection algorithm identifies and rewards predictive power rather than causal impact, and, as such, it does not offer any guarantee that the list of selected indicators coincides with the list of causal factors behind the differential effect of interest.

As an alternative more robust approach to assess the causal differential effect of various dimensions of environmental policy on services imports, the next exercise proposes to estimate, for total services trade as well as for the seven sector-specific services trade variables, the parameters of a large but tractable number of gravity regressions, each of them featuring a different combination of the selected interactions

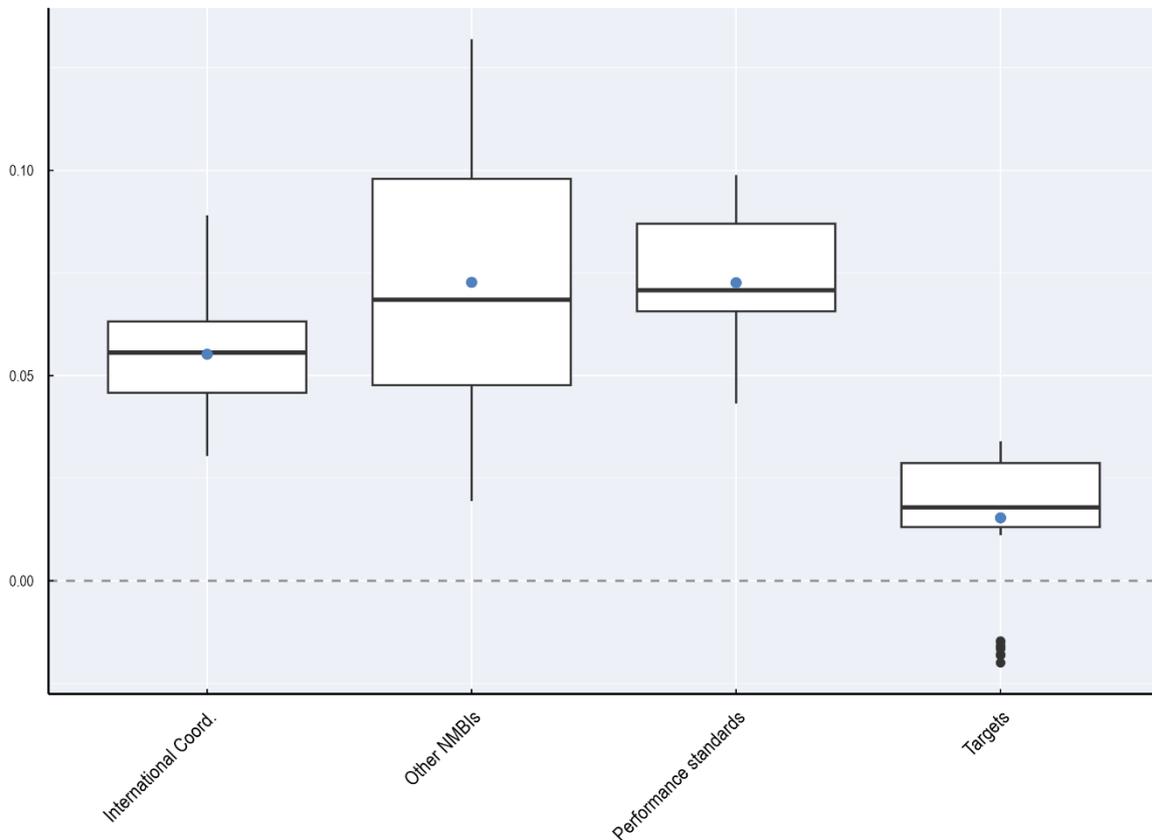
between environmental policy indicators and the international border dummy. This approach delivers for each services trade variable and environmental policy indicator a large number of estimated differential effects of the latter on the former. Studying the distribution of these estimated effects and their statistical significance leads to the most robust and preferred answers to the research questions tackled in this section.³³

More specifically, for each interaction term in the list of those selected by either plug-in or iceberg lasso as relevant predictors of a services trade variable, the following coefficients are estimated: (a) the coefficient of the interaction term included in isolation; (b) the coefficients of the interaction term in all possible combinations with another interaction from the list; (c) the coefficient of the interaction term in all possible combinations with two other interactions from the list. If, for example, a list includes all 11 interactions between CAPMF indicators and the international border dummy, this approach will produce 56 ((a)+(b)+(c) = 1+10+45 = 56) estimates of the differential effect on services trade for each indicator of environmental policy stringency. Figure 8 reports the box plots describing the distribution of the estimated differential effects on total services imports for the CAPMF indicators (listed on the horizontal axis).

The robust assessment of the differential effect of a specific dimension of environmental policy stringency for total services imports is built as follows. First, the differential effect of a policy-type CAPMF indicator is considered *insignificant* if more than 10% of its estimated differential effects have statistical significance lower than a 95% confidence level. This is the case for seven CAPMF indicators which are not reported in Figure 8. Second, the differential effect of each CAPMF indicator that satisfies the significance requirement is considered *positive* if all the statistically significant (at a 95% level) estimated differential effects are strictly greater than zero. This corresponds to the box plot lying completely above the horizontal line set at 0 in Figure 8. There are three types of environmental policies that satisfy this condition: performance standards; other non-market-based instruments; and international co-ordination policies. These types of environmental policy are considered robust causal factors increasing the relative use of international services with respect to domestic ones.

In a symmetric way, if the box plot of the estimated differential effect of an CAPMF indicator lies completely below the 0 line, it would lead to a robust assessment of a *negative* differential effect. No policy instrument type indicates this type of effect for total services imports. Finally, the assessment of a CAPMF indicator that satisfies the significance requirement is considered *inconclusive* if the vector of estimated differential effects associated to the indicator contains statistically significant positive and negative estimates. This is the case, for instance, for the CAPMF indicator capturing stringency through environmental targets in Figure 8.

³³ A similar is employed by Levine and Renelt (1992_[71]) to identify robust determinants of long-run average growth rates in cross-country growth regression settings.

Figure 8. Distribution of estimated differential effect of CAPMF indicators for total services imports

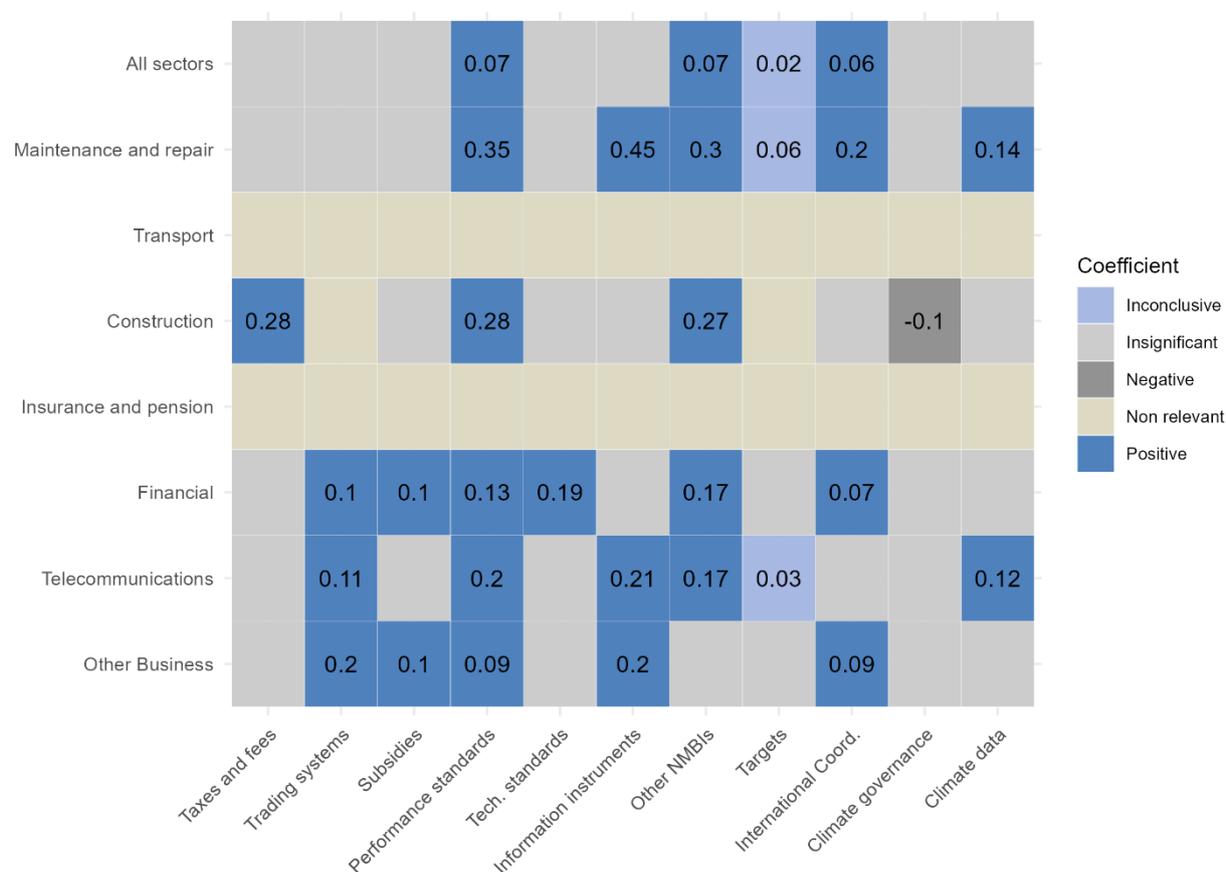
Note: For each CAPMF indicator listed horizontally, the figure shows the box plot of the distribution of all estimated differential effects of the CAPMF indicator on total services imports. These estimates correspond to the estimated coefficient of the interaction term between the international border dummy and the CAPMF indicator in the following gravity specifications: one where the interaction term of interest is included in isolation; all regressions where the interaction term is included in all possible combinations with another interaction term from the list of those selected by either plug-in or iceberg lasso as relevant predictors of services trade; and all regressions where the interaction term is included in all possible combinations with two other interaction terms from the list. Only those CAPMF variables with more than 90% of coefficients significant at the 95% confidence level are included. The plot also includes the mean value of all significant coefficients, represented in blue.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and CEPII.

4.1.4. Discussion of the differential effect of environmental policy

A similar assessment can be replicated for the seven sectoral services trade variables covered in the analysis (the relevant box plots of estimated effects for other sectoral categories of services trade are reported in Figure A D.3). All results are summarized graphically in Figure 9, which assigns the labels of *insignificant*, *inconclusive*, *positive*, and *negative* to the differential effect of environmental policy across all possible combinations of services trade variables and dimensions of environmental policy stringency. When the effect is considered not insignificant, the figure reports the mean estimated effect. In those cases where a CAPMF indicator is not selected as relevant for a services trade variable by the two-step lasso algorithm described above, the respective cell is labeled as *non-relevant*.

Figure 9. Summary of the robust assessment of the differential effects of environmental policy stringency on services imports with respect to domestic sourcing



Note: The matrix plotted in the figure characterises each combination of a sectoral category of services imports (row dimension of the matrix) and a dimension of environmental policy (column dimension) with a robust assessment of the estimated differential effect of the latter on the former. This robust assessment is performed by analysing a large but tractable number of estimated differential effects. If less than 90% of these coefficients are significant at the 95% confidence level the cell is labelled as *insignificant*. Colour-codes corresponding to positive and negative labels are assigned when all coefficients are either *positive* or *negative*. If the significance requirement is met, and at least two significant coefficients have a different sign, the cell is labelled as *inconclusive*. When the effect is considered not insignificant, the cell reports the mean estimated effect. In those cases where a CAPMF indicator is not selected as relevant for a services trade variable by the two-step variable selection algorithm, the respective cell is labelled *non relevant*.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

Figure 9 offers a rich set of robust empirical findings on the differential effects of environmental policy stringency on services imports. First, most of the significant relationships point to a positive effect. For total services imports, this is the case for three environmental policy instruments. Results for individual services sectors reveal that this pattern is driven by financial services (showing a positive differential effect from six types of environmental policies), maintenance and repair, telecommunications, and other business services (all with a positive effect from five policy-type CAPMF indicators). Looking at types of environmental policies, those that tend to exert a positive effect for the highest number of sectoral categories of services imports are performance standards, which positively impacts six sectoral categories; other non-market-based instruments (impacting five sectoral categories); as well as international co-ordination policies (affecting four categories of services imports).

Delving deeper into performance standards, which the results show as the most effective policy type, the evolution of service imports and policy stringency in countries such as Canada, the United Kingdom, and

Germany exemplifies the patterns embedded in the analysis. Canada has some of the largest service imports in the sample, with stringency increasing from a moderate level to the maximum by the end of the period. While Germany and the United Kingdom have lower levels of services imports, their increase in stringency levels are still very pronounced in the years covered (with their indices raising from around 2 to above 9 during the covered years). For all three countries, services imports show an increasing trend for most services sectors during our period of analysis.

Secondly, Figure 9 shows that in many more cases than those suggested by a less robust empirical assessment, environmental policy stringency does not disproportionately affect services imports with respect to domestic sourcing. This lack of a differential effect is particularly pronounced for transport and insurance and pension services, where no single dimension of environmental policy stringency seems to call for more services sourced from international markets than from domestic suppliers. Imports of construction services appear also not to disproportionately respond to higher stringency across many types of environmental policy. The policies which generate fewer differential effects across sectoral categories of services imports are taxes and fees, technology standards, and climate governance policies. While target-based policies seem to affect three different sectoral categories, in all cases they do so in an inconclusive manner.

Third, the magnitudes of the mean estimated differential effects reported in Figure 9 indicate that the strongest response to more stringent environmental policies can be expected for imports of maintenance and repair services. For this sector, the highest estimated differential effect is that from information instruments, equal to 0.45. This estimate implies that an increase of policy stringency by roughly half of a standard deviation of the corresponding CAPMF indicator (0.70), leads to a percentage change in imports of maintenance and repair services which is 40 percentage points higher than the percentage change in domestic sourcing.³⁴ If, for example, the hypothesized increase in environmental policy stringency leads to a 10% increase in domestic sourcing of maintenance and repair services, imports of these services would increase by 50%. This is a very large effect, significantly higher than those associated to the typical positive estimate reported in Figure 9. The average positive differential effect for total services imports is equal to 0.055, which implies that a one-unit variation in a CAPMF indicator leads to a percentage change in total services imports which is 5.65 percentage points higher than the percentage change in domestic sourcing.

Finally, one caveat of the analysis conducted to estimate the differential effect of environmental policy on services imports with respect to domestic sourcing is that services trade flows do not capture services imported through commercial presence, or mode 3 services imports. These are actually partly embedded in the measure of internal trade, which does not distinguish between the domestic or foreign ownership of firms that supply services domestically. While this represents a limitation for the analysis it does not jeopardize the robustness of the findings. These must be interpreted as differential effects of environmental policy on services imported through the modes of supply captured by the balance of payments framework, which forms the statistical basis of the BaTIS data.³⁵ Extending the analysis to mode 3 services imports is left for future research.

³⁴ The formula used for the economic quantification of the 0.45 estimate is the following. For a one unit increase in the CAPMF indicator, services imports would increase by $100(e^{0.45} - 1) = 57$ percentage points more than the percentage change in domestic sourcing. Half of a standard deviation in the CAPMF indicator is equal to 0.70, which implies that the associated percentage increase in services imports would be 40 percentage points higher than the percentage change in domestic sourcing.

³⁵ For most of the sectors analysed, these are notably mode 1 or cross border services trade, and mode 4 or trade by temporary movement of persons.

4.1.5. Beyond the differential effect

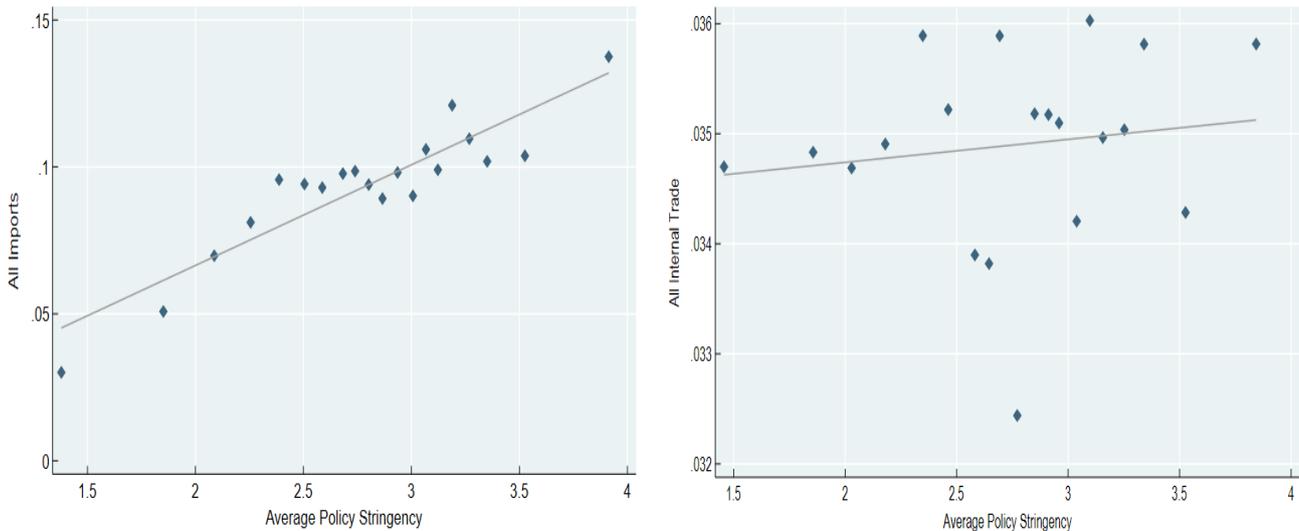
The overall assessment of a positive differential effect of environmental policy on services imports with respect to domestic sourcing does not provide any evidence on whether higher environmental standards increase services imports in absolute terms. For instance, a positive differential effect would be estimated even if higher standards lead to a reduction in the use of all services, but a smaller decrease for those sourced internationally. This scenario would contradict evidence highlighting the crucial role of services as key elements in many processes and solutions to achieve more ambitious environmental sustainability goals.

The empirical assessment of the absolute effect of environmental policy on services imports cannot rely on the structural gravity framework utilised so far. The reason for that is a technical one: the importer-time specific indicators of environmental policy would be perfectly collinear with and subsumed by the importer-time fixed effects, required by any structural gravity equation to account for the idiosyncratic pull factors characterising a specific importer at any given point in time. However, an econometrically sound correlation between environmental policy stringency and services imports can be estimated by fitting a panel regression model with data varying at the country and year level. While not allowing for a causal interpretation, this setting would contribute to shed some light on the relationship between environmental policy stringency and services imports, beyond the differential effect with respect to internal trade investigated so far.

The preferred specification chosen for this exercise takes (unilateral) total services imports as the dependent variable and the most aggregate CAPMF indicator of environmental policy stringency as the key regressor of interest. Identification relies on cross country variation after controlling for several country-year characteristics, including the size the economy (proxied by GDP), the level of economic development (GDP per capita), the share of manufacturing sector over GDP, inward FDI flows, as well as year-specific shocks common across countries. The same specification can be replicated with the measure of internal services trade as dependent variable, to complement the analysis with an estimate of the empirical linkages between environmental policy stringency and the use of services sourced from the domestic market.

The findings are illustrated graphically in Figure 10. To facilitate comparison between services imports and internal trade, the two dependent variables have been rescaled to vary between 0 and 1. 0 reports summary statistics and detailed regression estimates for this exercise.

The empirical relationship between environmental policy stringency and total services imports is positive and statistically significant (left panel in Figure 10). It remains positive but loses statistical significance when services imports are replaced by the measure of internal trade (right panel). Overall, these findings suggest that countries facing higher environmental policy stringency tend to import more services from international markets rather than showing stronger patterns of domestic sourcing. This aligns well with the positive effect of higher environmental standards on services imports compared to domestic sourcing and confirms that trade is a key channel for accessing services required to tackle more ambitious environmental sustainability objectives.

Figure 10. Effect of CAPMF on internal trade and total imports

Note: These two scatter plots show the results of regressions between the total amount of internal trade (panel A) and imports (panel B) on the country average CAPMF index. The dependent variable was rescaled on both cases for comparability, and it ranges between 0 and 1. Both regressions include year fixed effects, and controls for the main country-time macroeconomic variables (GDP, GDP per capita, share of manufacturing sector GDP, inward FDI flows). The dots represent the bins generated from clustering of residuals to account for all relevant controls. For internal trade, the CAPMF coefficient was found insignificant, while it is significant at the 99% level for imports.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and CEPII.

4.2. Does environmental policy affect the linkages between trade in services and environmental performance?

After having established that environmental policy is a robust driver of higher services imports, this section empirically investigates the role of environmental policy in shaping the relationship between services trade and the environment driven by the technique channel. The analysis builds on the empirical exercises in Section 0, extending them to examine how environmental policy stringency affects the estimated linkages in both a cross-country setting (Section 3.1), and along supply chains (Section 3.2). In both frameworks, complementarity and substitutability between services trade and environmental policy may simultaneously influence the results, making the direction of the moderating effect of environmental policy ambiguous. Details on how Section 0 frameworks are adapted to analyse this moderating role are available in Annex E.

4.2.1. Evidence from cross-country analysis

Whether higher services imports are associated with stronger environmental performance in countries where stricter environmental policy is in place, remains an empirical question. The interplay between complementarity (i.e. environmental policy triggering or amplifying a positive effect of services imports on environmental performance) and substitutability (i.e. services imports substituting for less stringent environmental policies in generating technical changes for sustainability) likely varies across policy types and dimensions of environmental sustainability performance. While a detailed theoretical investigation into these interactions lies beyond the scope of this paper, a preliminary descriptive assessment is provided to identify regularities and cases for future research.

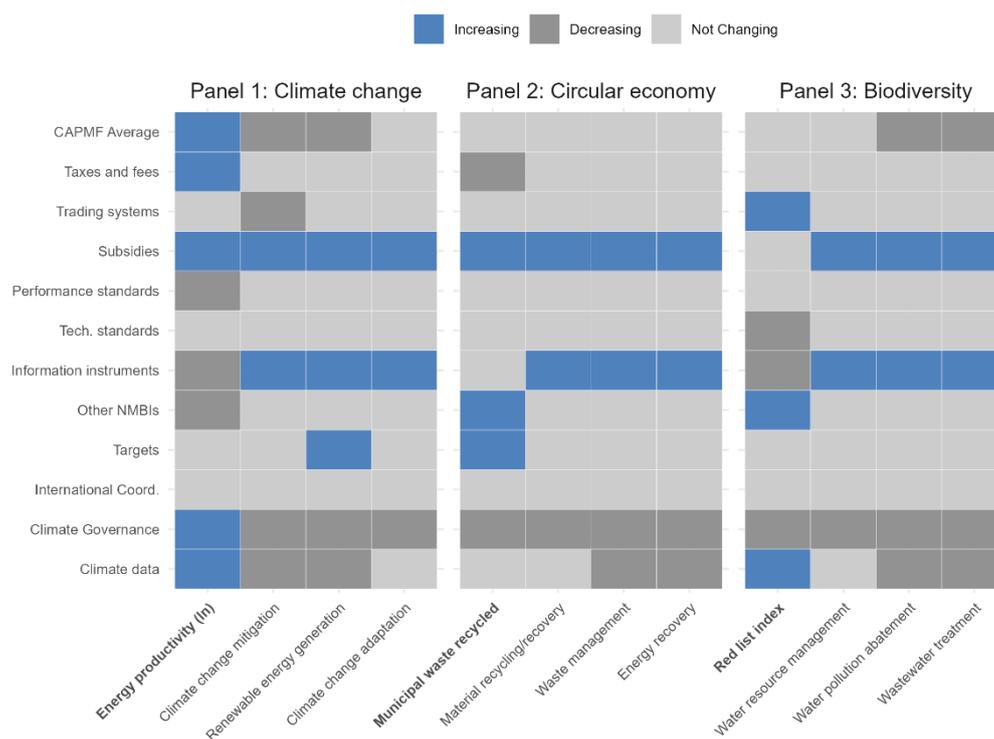
The regression equations from Section 3.1, which analyse the relationship between total services imports (as the main regressor of interest) and indicators of environmental sustainability performance (as dependent variables), are augmented with two additional terms: an indicator of environmental policy

stringency at the country-year level and its interaction with total services imports. The sign and statistical significance of the estimated coefficient of this interaction term provide a qualitative indication of how environmental policy stringency moderates the link between services imports and environmental performance through the technique channel.

The analysis uses the same set of environmental performance indicators as in Section 0, categorised under climate change, circular economy, and biodiversity. It incorporates measures of environmental policy stringency from the CAPMF database, including both the aggregate, synthetic stringency indicator and the 11 indicators of individual policy types.

Figure 11 illustrates the results. Each cell in the matrix represents the estimated coefficient of the interaction term between services imports and environmental policy stringency, based on regressions defined by specific environmental performance indicators (columns) and CAPMF indicators (rows). The cell colour reflects whether higher environmental policy stringency strengthens (blue colour, label “increasing”) or weakens (dark grey, “decreasing”) the empirical relationship in favour of a positive technique channel. Statistically insignificant results are labelled accordingly, indicating no variation in the relationship with environmental policy stringency (light grey, “not changing”).

Figure 11. Environmental policies shaping the linkages between services imports and environmental performance indicators



Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with services trade on environmental performance indicators. Those indicators in bold represent environmental outcomes, while the rest are innovation indicators. The estimations include year fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval.

Source: CAPMF, BaTIS, Green growth indicators, Patents technology dataset, Our World in Data.

The results reveal multifaceted empirical evidence, with contrasting patterns across different policy types and, to a lesser extent, environmental performance indicators. For example, using the aggregate CAPMF indicator (first row of the matrices), higher policy stringency strengthens the relationship between services imports and energy productivity, supporting the technique channel. Conversely, the relationship weakens for two of three green innovation indicators within the climate change and biodiversity clusters. For circular economy indicators, no significant changes are observed with varying policy stringency.

These patterns change by type of policy instruments. Higher environmental policy stringency through subsidies and information instruments appears as a complementary force that can promote and support the realisation of positive linkages between services imports and green innovation. The opposite pattern emerges for policies related to climate governance and climate data. Energy productivity is the indicator of environmental performance where complementarity between services imports and environmental policy stringency seems more widespread across different policy types. These include taxes and fees, subsidies, policies related to climate governance and climate data.

For many environmental policy instruments, however, environmental policy stringency does not significantly affect the relationship between services imports and environmental performance. This is particularly true for technical standards and policies related to international co-ordination. Similarly, most individual policy types show limited influence on the relationship between services imports and pollution intensity indicators (Figure A E.1). Nevertheless, when aggregated into the CAPMF indicator, stricter environmental policies are associated with stronger support for a positive technique channel in the relationship between services imports and pollution intensity.

Using services trade restrictiveness measures instead of total services imports yields similarly heterogeneous results (Figure A E.2 and Figure A E.3). Moreover, in a more demanding specification that tests the robustness of these estimates—controlling for measures of economic development and including country fixed effects—nearly all estimates lose statistical significance (Figure A E.4-Figure A E.7). Consistent with the discussion in Section 3.1, these estimates therefore cannot support robust or precise causal claims. Instead, they only provide descriptive evidence highlighting the interplay of opposing forces—complementarity and substitutability—that shape how environmental policy mediates the impact of services trade and services trade policy on environmental sustainability. These results underscore the need for further research into these dynamics.

4.2.2. Evidence from manufacturing supply chains analysis

Complementarity and substitutability are likely to simultaneously influence the relationship between environmental policy stringency and services trade openness in shaping the positive impact of the latter on the environmental performance of manufacturing sectors downstream in supply chains, as estimated in Section 3.2. On the one hand, stricter environmental regulations may encourage firms in downstream manufacturing sectors to fully leverage the potential of foreign services inputs in supporting the technical changes required to meet more ambitious environmental standards. This complementarity would lead to a stronger effect of services trade reforms on the reduction of manufacturing CO₂ emissions intensity in countries with higher environmental policy stringency. On the other hand, increased access to foreign services inputs may substitute for environmental policy and play a more critical role in countries where less strict environmental standards have left the domestic economic system with fewer tools and resources to drive technical changes towards greener manufacturing production processes.

To test whether lower trade barriers to import services inputs decrease manufacturing environmental footprint more in countries with higher or lower environmental policy stringency, the regression equation for CO₂ emission intensity at the country-sector-year level estimated in Section 3.2 is augmented here with the interaction between the indicator of upstream services trade restrictiveness and a measure of environmental policy stringency. A positive and statistically significant estimated coefficient of this interaction term would reflect a prevailing complementarity between services trade policy and

environmental standards. Instead, a negative and significant estimate would suggest that services trade reforms tend to substitute for environmental regulations in triggering the technical change required to make manufacturing sectors less polluting.

Estimations are derived using the same data as in Section 3.2, augmented with measures of environmental policy stringency sourced from the CAPMF database. The aggregate stringency index, and the 11 policy-type indicators introduced above are used in separate regressions.

In none of these estimations the coefficient of the interaction term between upstream services trade restrictiveness and environmental policy stringency meets the minimum standard for statistical significance.³⁶ These findings may reflect lack of statistical power to identify the moderating role of environmental policy stringency at the country-time level in specifications with country-time, sector-time and country-sector fixed effects. However, results are also fully consistent with the assumption of simultaneous complementarity and substitutability between services trade openness and environmental policy stringency.

5 Conclusions

As the world faces the pressing need to balance economic growth with environmental sustainability, understanding how services trade—given its growth over the past decades and its crucial role in shaping international supply chains—can influence and drive sustainability efforts is more important than ever. In fact, services sectors such as engineering, architecture, management consulting, or maintenance and repair can potentially offer innovative solutions that contribute to environmental sustainability.

This paper adds to the growing debate on the role of services trade in environmental sustainability by providing new insights and empirical evidence on the linkages between services trade and the environment. The analysis highlights the importance of services trade in supporting technological advancements that mitigate environmental risks related to climate change, promote the circular economy, and protect biodiversity.

Estimated correlations between higher imports or lower services trade barriers and green innovation, as well environmental outcomes, are particularly strong and consistent in sectors such as research and development, professional and management consulting services, technical and scientific services (including architecture and engineering), core environmental services, and telecommunications. Additionally, more robust econometric findings show that removing policy restrictions to services imports significantly reduces CO2 emissions intensity in manufacturing sectors that rely on these services.

This analysis provides a strong rationale for advancing policy efforts to design and implement services trade reforms that support environmental sustainability. It aligns with recent initiatives, such as APEC's list of environmentally related services, activities under the TESSD initiative at the WTO, and the environmental services chapter in the ACCTS. In particular, the results suggest that reforms targeting services sectors supplying key inputs to downstream manufacturing can significantly reduce production-based pollution.

The paper also highlights that other mechanisms might be influential alongside the technique channel tested empirically. Increased openness to services trade can alter international specialization patterns and shift sectoral compositions, which in some cases may increase environmental pressures. Further research is needed to assess the environmental impact of services trade through this composition channel, both theoretically and empirically.

³⁶ Estimation results are available upon requests.

Additionally, it underscores the interdependencies between environmental policies and services trade, offering insights to guide integrated policy actions. Econometric results show that stricter environmental standards can significantly boost services imports. The analysis also reveals both complementary and substitutive relationships between services imports and environmental policy in driving technological advancements for sustainability.

Findings suggest that stricter environmental regulations can amplify the sustainability impact of foreign services by creating incentives to use these services to achieve higher standards. Conversely, services imports can support sustainability goals more effectively in contexts with weaker standards, where the domestic ecosystem for environmental sustainability is limited, and foreign services play a critical role in introducing effective solutions. Further analytical work on the interplay between services trade and environmental policy will help policymakers prioritise efforts across these interconnected areas.

Overall, this paper proposes a conceptual and empirical analysis to raise awareness of the crucial role of services trade in supporting the green transition. Moving forward, stronger empirical evidence is needed to continue informing evidence-based services trade policymaking. This requires refining services trade restrictiveness measures to better capture regulatory impacts on trade and the environment.

Ongoing efforts under the OECD Trade Committee to extend the OECD Services Trade Restrictiveness Index (STRI) Database to cover environmental services represent an important step in this direction. Replicating some of the exercises presented here with new STRI data, alongside developing new econometric approaches to estimate the environmental impact of specific trade policy reforms —extending previous work (Benz et al., 2023^[39])—can further advance the research agenda on services trade and the environment.

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Annex A. Selected case studies

Table A A.1. Selected case studies on services trade and environmental sustainability

Case study	Involved services	Country aspects	Mode (if available)	Industry (ISIC Rev.4)	Environmental objective	Main message	Source
GE Flexible wind services	Consulting Maintenance and repair Monitoring	Services deployed worldwide, mainly America, also Europe and Asia	Mainly mode 3, with the other three modes also available	Production, collection, and distribution of electricity (3510)	Climate change mitigation and adaptation	These services maximize the renewable energy output while reducing its costs, through the companies remote monitoring and expertise	(Steenblik and Grosso, 2011 ^[50])
Steel sector's voluntary approach	Consulting Evaluation Technology diffusion	International	No modes of provision discussed	Manufacture of basic iron and steel (2410)	Climate change mitigation and adaptation Support of circular economy	An international voluntary community that promotes technology sharing and information services to green the steel industry	(Okazaki and Ono, 2012 ^[51])
PII Pipeline Solutions	Monitoring Risk assessment	United States Belgium France	Modes 1 and 2	Distribution of gaseous fuels through mains (3520)	Biodiversity protection	A firm that provides state-of-the-art monitoring and assessment services to prevent leaks and ensure optimal functioning of pipelines	(Steenblik and Grosso, 2011 ^[50])
MT-Energie	Construction Consulting training technical support	Germany, with subsidiaries in other 10 countries	Modes 3 and 4	Production, collection and distribution of gaseous fuels through mains (3511)	Climate change mitigation and adaptation	A multinational firm that constructs and provides support in functioning of biogas production plants	(Steenblik and Grosso, 2011 ^[50])
Kamphaeng Saen Landfill	Construction Operation Maintenance technical support	Thailand, and France (firm)	Modes 3 and 4	Distribution of gaseous fuels through mains (3520)	Support of Circular economy Climate change mitigation and adaptation	A French firm that builds, operates and maintains landfill gas production plants, which aim at reusing the byproducts of waste management into new ways of producing renewable energy	(Intharathir at and Abdul Salam, 2016 ^[52])
City of Nykping contract with TAC Energy Solutions	Installation Monitoring Operation	Sweden	No modes of provision discussed	Production, collection, and distribution of electricity (3510)	Climate change mitigation and adaptation	A Swedish city enters into a contract with a German firm to reduce energy consumption and GHG emissions of the buildings in the city, by installing solar panels and heat pumps as well as by other energy efficiency improvements.	(Steenblik and Grosso, 2011 ^[50])
TaKaDu	Data analysis Monitoring technical support	Israel (firm) Austria, Australia, Netherlands , UK	Mode 1	Water collection, treatment and distribution activities (3600)	Climate change mitigation and adaptation	A data-centric Israeli firm that uses advanced algorithms to detect water loss and other anomalies, contributing to the efficient use of an essential natural resource.	(Armon et al., 2011 ^[53])

Case study	Involved services	Country aspects	Mode (if available)	Industry (ISIC Rev.4)	Environmental objective	Main message	Source
TNT Eco-logistics Services	Transport Logistics	International	No modes of provision discussed	Other transportation support activities (5229)	Climate change mitigation and adaptation	A multinational logistics firm that provides greener transport services, through the use of hybrid and electric trucks. They aim to become the first zero-emissions logistics firm.	(Steenblik and Grosso, 2011 ^[50])
EcoSecurities carbon services	Financial services Consulting	Ireland-EU	No modes of provision discussed	Securitisation activities (6494)	Climate change mitigation and adaptation	Firm that provides carbon finance expertise to projects reducing GHG emissions. They fund and help drafting carbon mitigation projects	(Zambujal-Oliveira, Henriques and Henriques, 2011 ^[54])
Netafim	Consulting Installation technical support training	International	Mainly mode 3, with the other three modes also available	Support activities for crop production (1610)	Climate change mitigation and adaptation Biodiversity protection	Firm that provides services in development of irrigation systems, increasing efficiency in water and fertilizer use, minimizing environmental damage and resource usage	(Barak, 2012 ^[55])
Geothermal energy and development	Consulting technical support training	New Zealand (home), Indonesia, Caribbean, Africa	No modes of provision discussed	Production, collection, and distribution of electricity (3510)	Climate change mitigation and adaptation	New Zealand state provides consulting and support services to other states and international entities to develop geothermal energy plants. This increases efficiency and productivity of more renewable energies	(New Zealand, 2024 ^[56])
Wind offshore energy	Consulting Installation technical support Operation Maintenance and repair	No specific countries	No modes of provision discussed	Production, collection, and distribution of electricity (3510)	Climate change mitigation and adaptation	UK wind energy firm provides in-depth analysis of the potential products of offshore wind facilities	(United Kingdom, 2023 ^[57])
Hydrogen energy and trade	Engineering Construction Operation and Maintenance Certification and testing RDD Consulting Insurance and financing	No specific countries	No modes of provision discussed	Production, collection, and distribution of electricity (3510)	Climate change mitigation and adaptation	UK Study on the Green Hydrogen sector. It provides an analysis on the sectors that are usually involved in the supply chain of green hydrogen production.	(United Kingdom, 2023 ^[58])
Wastewater and solid waste treatment in Indonesia Link	Construction Operation Maintenance Consulting	Indonesia	No modes of provision discussed	Water collection, treatment and distribution activities (3600) Collection of non-hazardous waste (3811)	Climate change mitigation and adaptation Support of circular economy	Study on concessions done by the Indonesian government to foreign firms for construction, improvement and operation of water waste and waste management plants.	(OECD, 2001 ^[59])

Case study	Involved services	Country aspects	Mode (if available)	Industry (ISIC Rev.4)	Environmental objective	Main message	Source
Water supply, wastewater and solid waste treatment in Malaysia Link	Construction Operation Maintenance Consulting Monitoring	Malaysia	No modes of provision discussed	Water collection, treatment and distribution activities (3600) Collection of non-hazardous waste (3811)	Climate change mitigation and adaptation Support of circular economy	Study on concessions done by the Malaysian government to foreign firms for construction, improvement and operation of water waste and waste management plants. More detailed study on monitoring efforts of responsible management of solid waste.	(OECD, 2001 ^[59])

Note: Authors' elaboration using sources indicated in the table.

Annex B. Supporting material for Section 3.1: Cross-country evidence of the technique channel

Empirical strategy

To produce econometrically sound estimations of the correlation between measures of services trade (as main regressors of interest) or services trade policy (STRI) and indicators of environmental sustainability (as outcome variables),³⁷ country (i) – year (t) level panel regressions with year fixed effects are estimated. Such estimations are augmented with control variables that control for scale, composition, and technique channels. The following equation allows the empirical investigation of how the relationships between services trade (or alternatively services trade policy) and environmental sustainability varies across countries, in a given year (Equation (1)):³⁸

$$y_{it} = \beta_0 + \beta_1 Z_{it-1} + \beta_2 \log(\text{Trade})_{it-1} + \beta_3 \log(\text{GDP})_{it-1} + \beta_4 \text{FDI}_{it-1} + \beta_5 \text{Ind}_{it-1} + \varepsilon_{it} \quad (1)$$

where y_{it} is in turn equal to each of the environmental performance indicators listed indicated in Table A B.2. The primary data sources for the environmental performance indicators are OECD databases such as the Air and greenhouse gas (GHG) emissions databases, the Green Growth Indicators database (Green Growth Indicators), and green patents data. Other complementary data comes from Our World in Data's biodiversity indicators.³⁹

The variable of interest Z_{it} consists in turn of: (i) total services imports or services import flows distinguished by type of service; (ii) the trade restrictiveness index (STRI), introduced distinctly by type of STRI. The main source of services trade is the OECD-WTO Balanced Trade in Services Statistics (BaTIS) (Liberatore and Wettstein, 2021_[60]). The main source of information on services trade policy will be the OECD Services Trade Restrictiveness Index (STRI) Database.

Control variables include: $\log(\text{Trade})_{it-1}$ which consists in the sum of exports and imports of country i ; GDP_{it-1} a measure of Gross Domestic Product (GDP) to control for the scale effect, with data coming from the IMF national account statistics; the manufacturing share of GDP, Ind_{it-1} , which controls for the composition channel; FDI_{it-1} , the foreign direct investment inflow in a country capturing the technique channel. FDI data is sourced from UNCTAD. All independent variables are lagged by one year to allow for a minimum time gap between the realisation of services trade flows or policies and environmental performance. Standard errors use the robust estimator for variance in all regressions.

Additional results

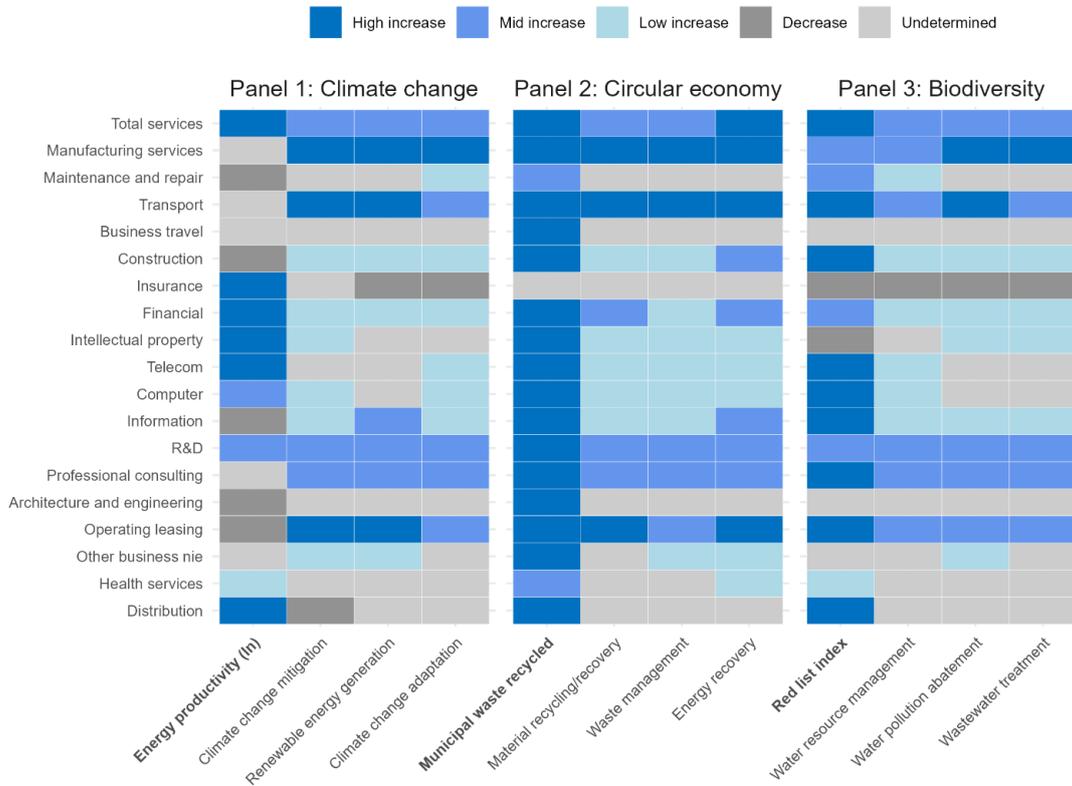
As an alternative source to the BaTIS database for services import flows, estimates were also produced using WTO's Trade in services by modes of supply (TISMOS) database. The advantages of this database are its accounting of mode 3 services trade, as well as the larger services sector disaggregation, in particular in the other business services category. The same estimations as for BaTIS services trade were run for each TISMOS services imports category, with results being shown in Figure A B.1 and Figure A B.2.

³⁷ Similar settings can also be applied to estimate the relationship between services trade policy at the country-year level and indicators of environmental sustainability.

³⁸ This estimation equation is similar to what is implemented by Aller, Ductor and Herrerias (2015_[72]).

³⁹ See Table A B.2 for a complete list of sources and country coverage information.

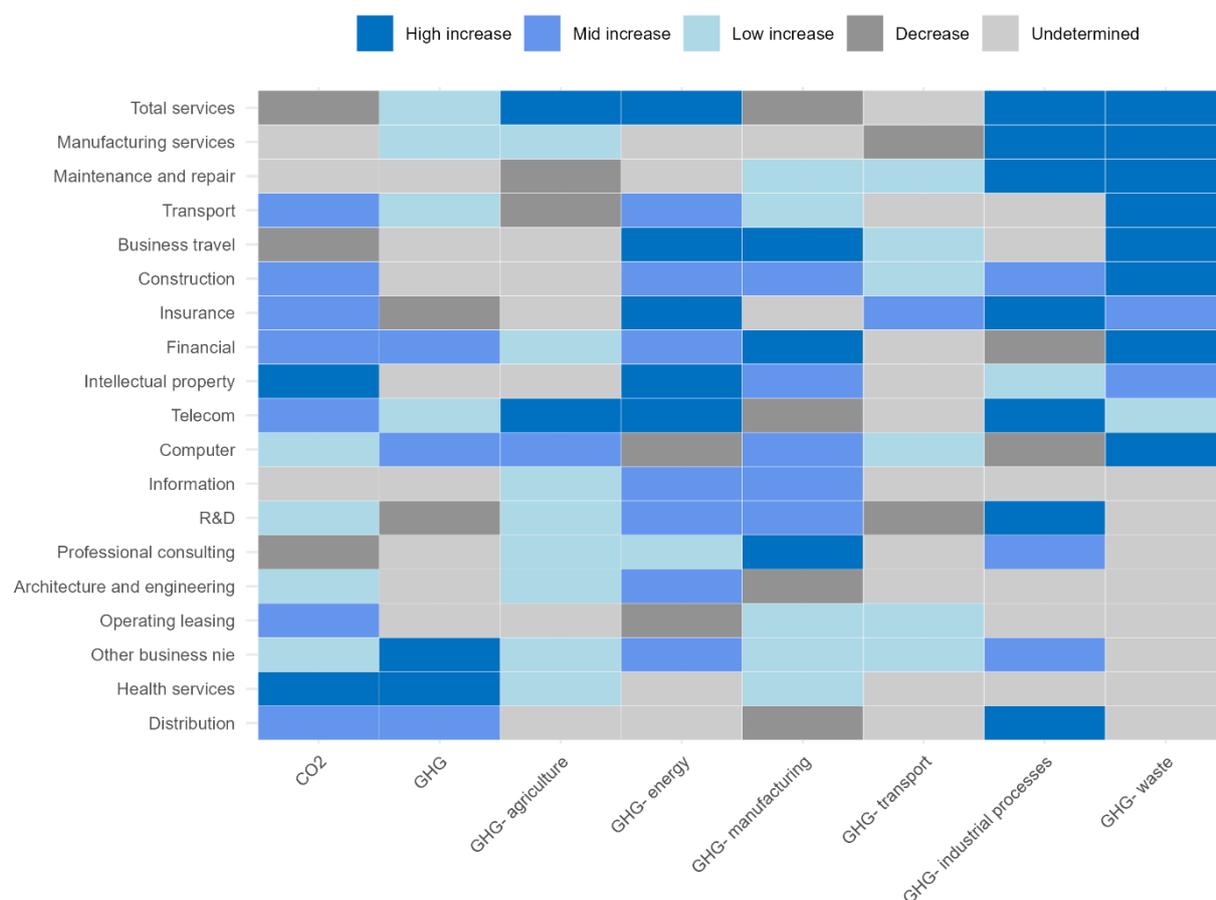
Figure A B.1. TISMOS services imports and environmental performance indicators



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and environmental performance, the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: TISMOS database, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A B.2. TISMOS services imports and emission intensity indicators

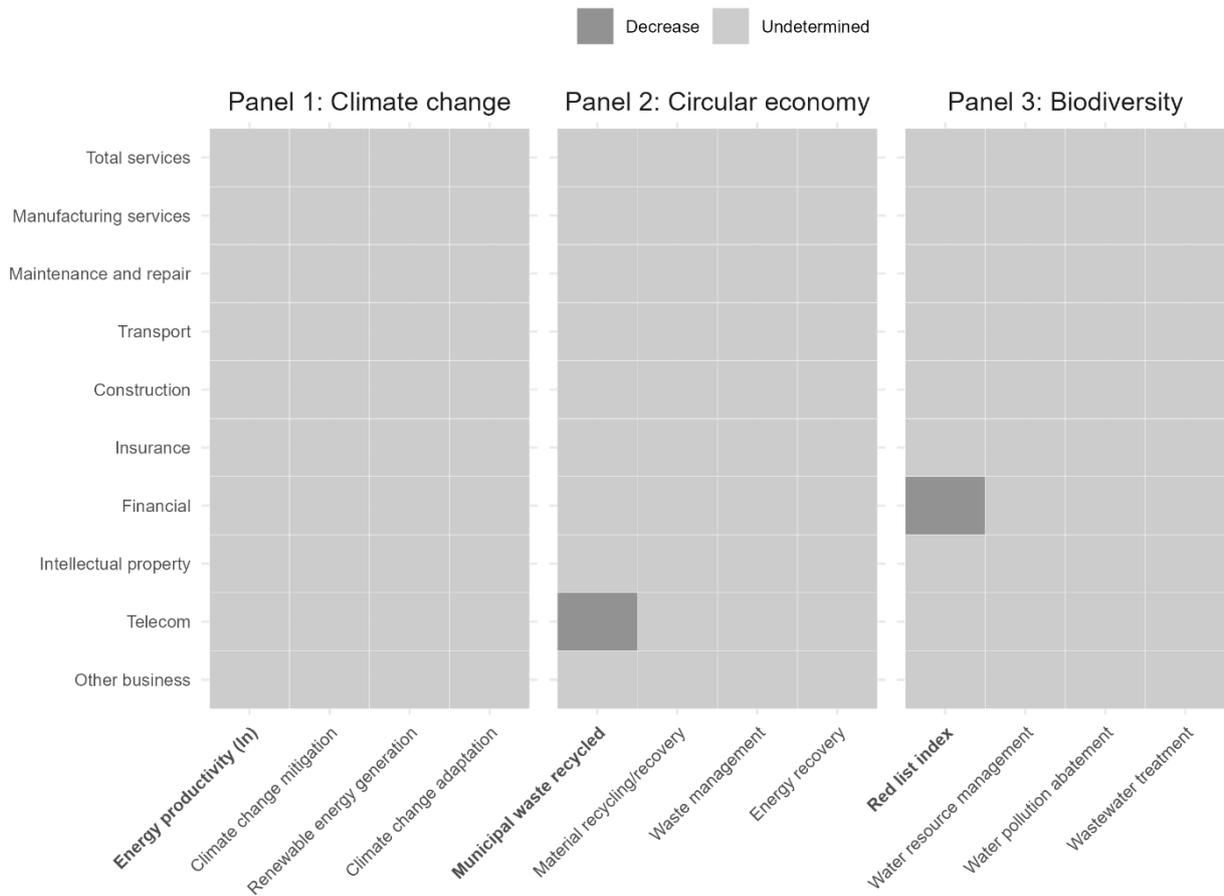


Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as year fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and sustainability performance (which is equivalent to a decrease in emission intensity, which is showcased by a negative coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: TISMOS database, OECD Air and GHG emissions database.

The six figures down below present results from a more demanding version of Equation (1) for estimations with BaTIS services imports (Figure A B.3 and Figure A B.4), the STRI (Figure A B.5 and Figure A B.6) and TISMOS services imports (Figure A B.7 and Figure A B.8). In addition to the existing set of controls and fixed effects, this estimation includes controls for economic development through the inclusion of GDP per capita and its quadratic term, as well as country fixed effects to limit the estimation to within-country over time variation.

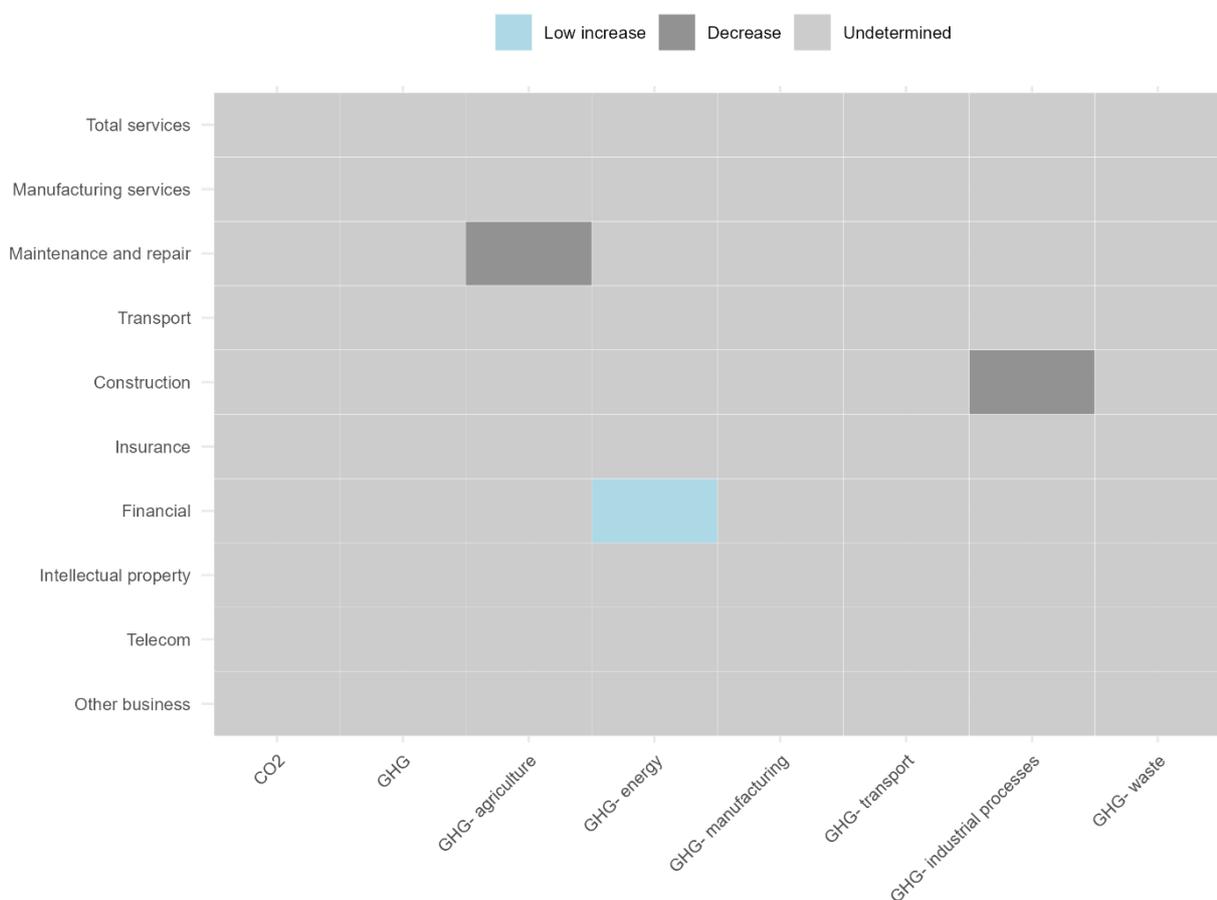
Figure A B.3. Services imports and environmental performance indicators
(with country fixed effects and economic development controls)



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and environmental performance, the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species. Source: BaTIS database, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A B.4. Services imports and emission intensity indicators

Estimations with country fixed effects and economic development controls

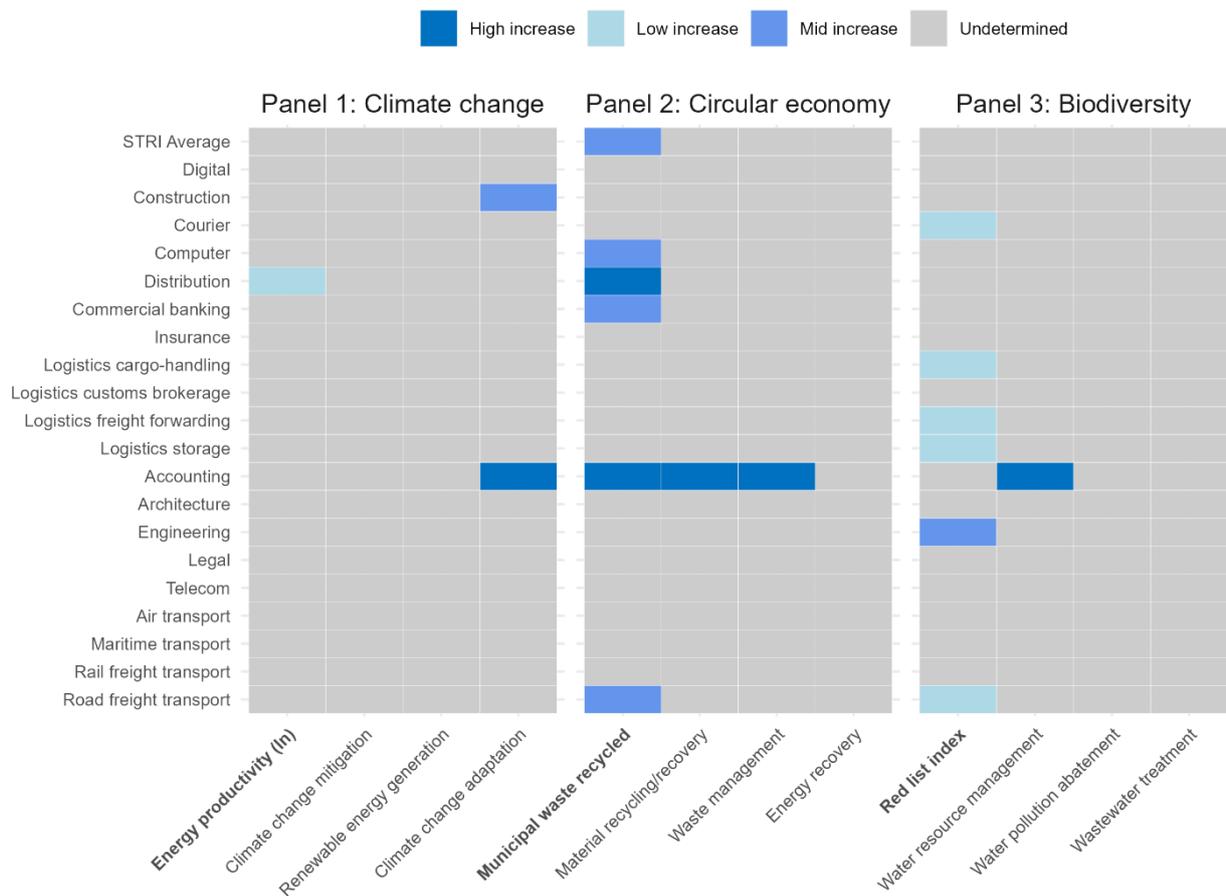


Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and sustainability performance (which is equivalent to a decrease in emission intensity, which is showcased by a negative coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: BaTIS database, OECD Air and GHG emissions database.

Figure A B.5. Services restrictiveness and environmental performance indicators

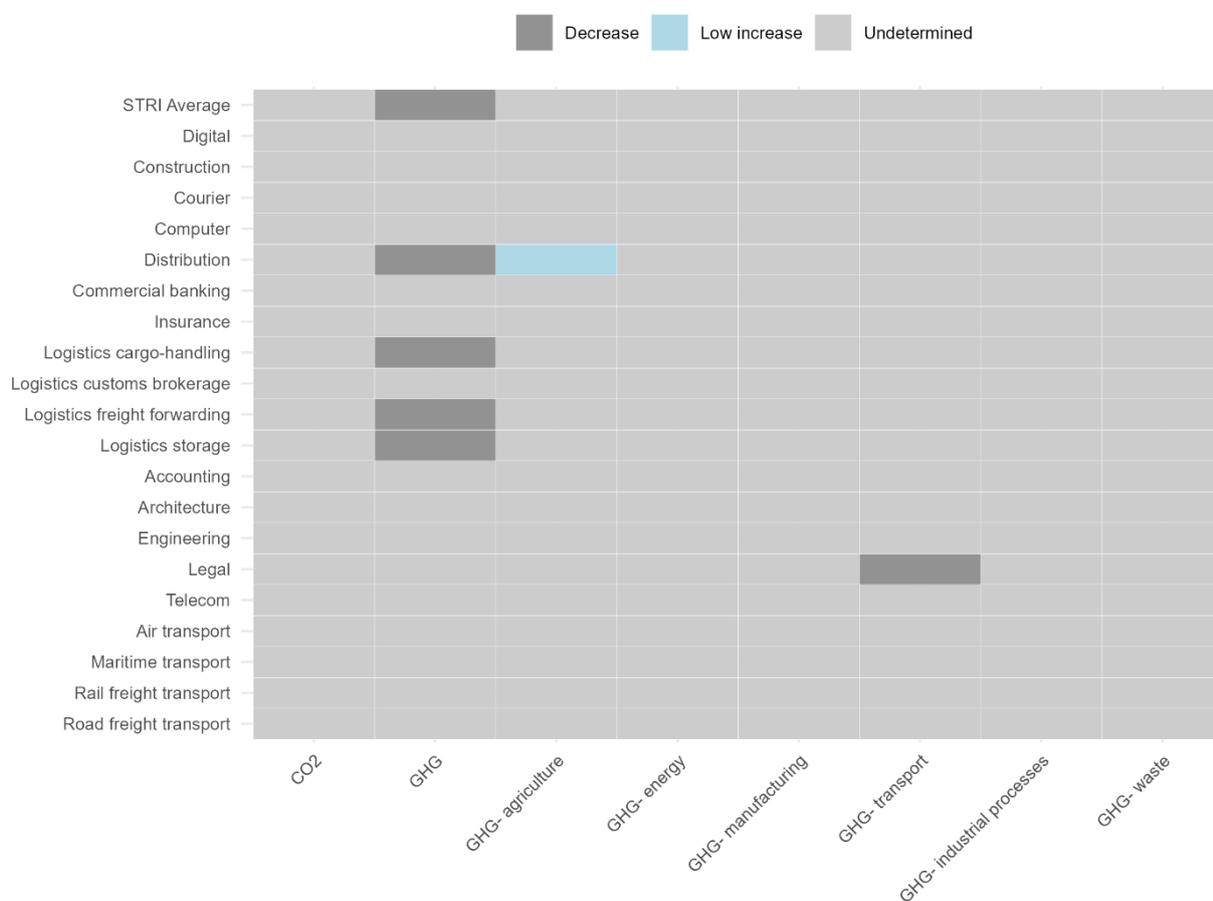
Estimations with country fixed effects and economic development controls



Note: This figure visually presents the estimated coefficients capturing the relationship between different categories of the STRI (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services restrictiveness reduction and environmental performance (which is showcased by a negative coefficient, as services trade liberalisation is associated with a reduction in the STRI), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species.

Source: OECD STRI database, Green growth indicators, Patents technology dataset, Our World in Data.

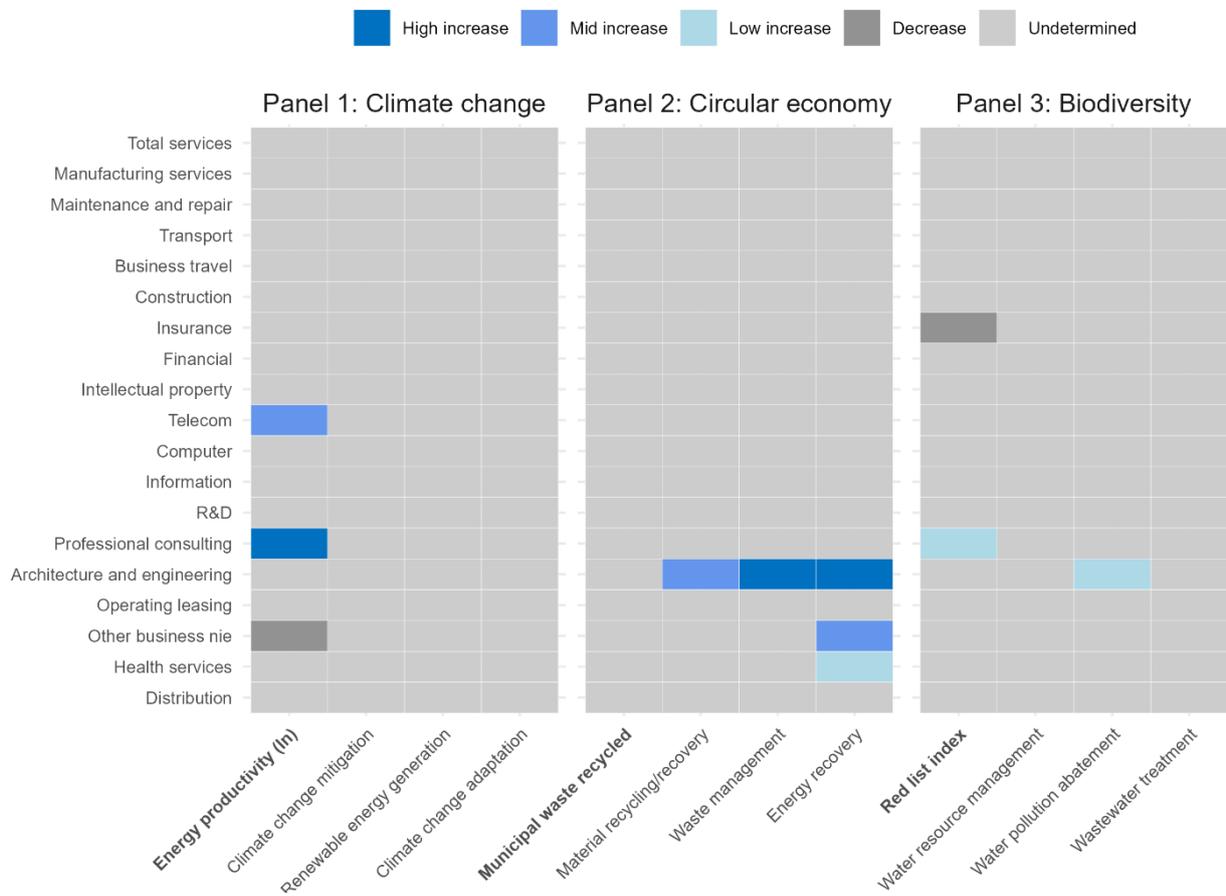
Figure A B.6. Services restrictiveness and emission intensity (with country-fixed effects and economic development controls)



Note: This figure visually presents the estimated coefficients capturing the relationship between different categories of the STRI (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services liberalisation and sustainability performance (which is showcased by a positive coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a "high increase", those between the 33rd and 66th percentiles as a "medium increase", and those below the 33rd percentile as a "low increase". The label "Manufacturing services" refers to "Manufacturing services on physical inputs owned by others." The Red List Index tracks trends in overall extinction risk for species.

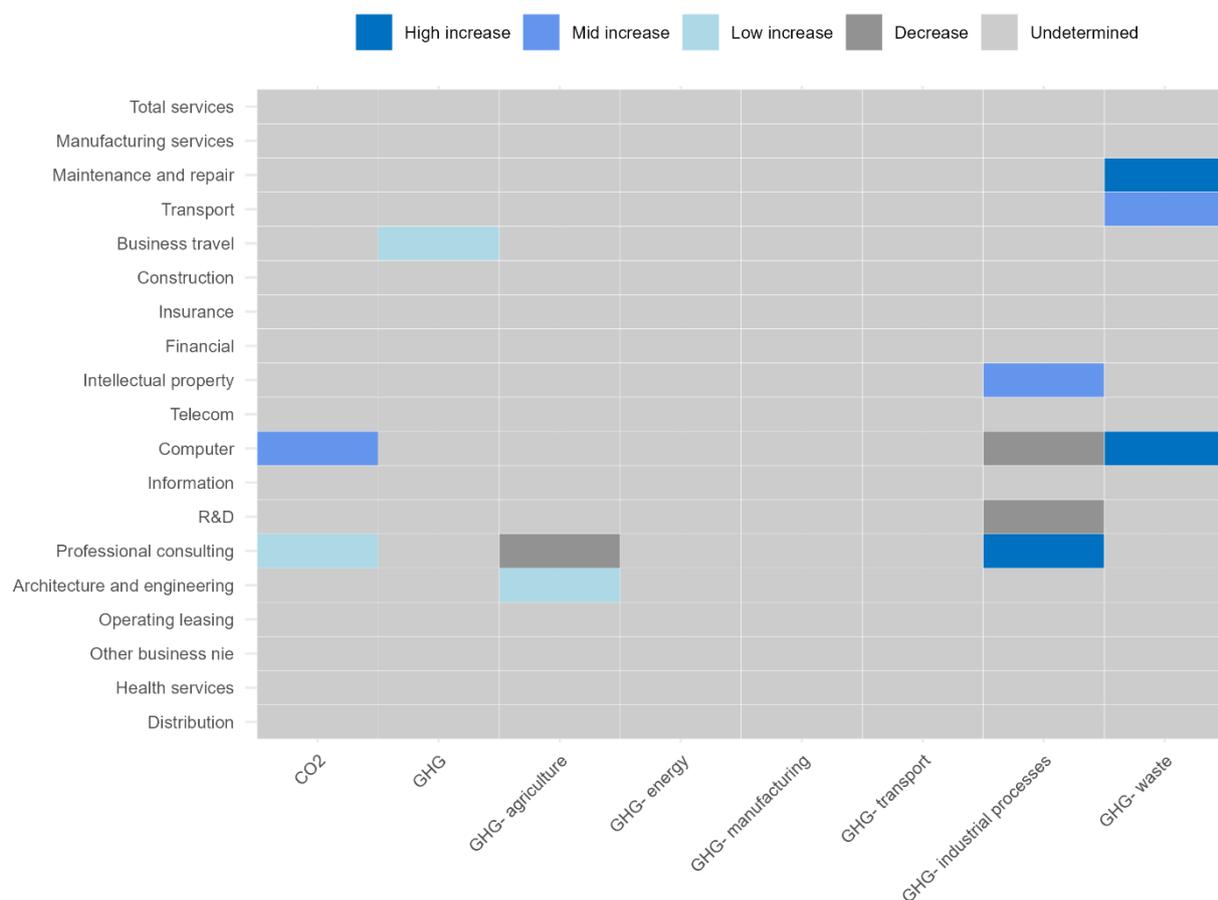
Source: OECD STRI database, OECD Air and GHG emissions database.

Figure A B.7. TISMOS services imports and environmental performance indicators (with country-fixed effects and economic development controls)



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and environmental performance indicators (listed horizontally). Among the latter, those in bold represent environmental outcomes, while the others reflect environmental innovations (e.g. “Climate change mitigation” refers to the number of environment-related inventions presented at patent offices for climate change mitigation technologies). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and environmental performance, the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across environmental performance indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a “high increase”, those between the 33rd and 66th percentiles as a “medium increase”, and those below the 33rd percentile as a “low increase”. The label “Manufacturing services” refers to “Manufacturing services on physical inputs owned by others.” The Red List Index tracks trends in overall extinction risk for species. Source: TISMOS database, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A B.8. TISMOS services imports and emission intensity indicators (with country-fixed effects and economic development controls)



Note: This figure visually presents the estimated coefficients capturing the relationship between different types of services imports (listed vertically) and emission intensity indicators (listed horizontally). Each underlying regression includes controls for the scale and composition effects in the relationship between services trade and environmental sustainability, as well as controls for economic development, year and country fixed effects. Cells are colour-coded to indicate whether the estimated coefficient suggests that higher services imports are associated with an increase (various shades of blue) or a decrease (dark grey) in sustainability performance. If the estimate is not statistically significant at least at the 95% level, the relationship is classified as undetermined (light grey). When a positive relationship is found between services imports and sustainability performance (which is equivalent to a decrease in emission intensity, which is showcased by a negative coefficient), the heatmap further differentiates between high (dark blue), medium (medium blue), and low increases (light blue). To account for differences in measurement scales across emission intensity indicators, coefficients are standardised in terms of standard deviations. Standardised coefficients above the 66th percentile of all coefficients reflecting a positive relationship between services imports and environmental performance within each matrix are categorised as a "high increase", those between the 33rd and 66th percentiles as a "medium increase", and those below the 33rd percentile as a "low increase". The label "Manufacturing services" refers to "Manufacturing services on physical inputs owned by others." The Red List Index tracks trends in overall extinction risk for species. Source: TISMOS database, OECD Air and GHG emissions database.

Other supporting materials

Table A B.1. List of countries included in the estimations

OECD Members			Accession candidates	
AUS	ESP	JPN	SVK	ARG
AUT	EST	KOR	SVN	BGR
BEL	FIN	LTU	SWE	BRA
CAN	FRA	LUX	TUR	HRV
CHE	GBR	LVA	USA	IDN
CHL	GRC	MEX		PER
COL	HUN	NLD		ROU
CRI	IRL	NOR		THA
CZE	ISL	NZL		
DEU	ISR	POL		
DNK	ITA	PRT		

Note: This table lists OECD Members and accession candidates covered in most estimations reported in Section 3.1. In certain estimations, the year coverage might differ between countries due to data availability.

Table A B.2 Environmental performance indicators

Name	Short label	Description of the measure	Countries not covered
Climate change adaptation and mitigation			
Energy productivity, GDP per unit of TES (USD/toe)	Energy productivity (ln)	It reflects, at least partly, efforts to improve energy efficiency and to reduce carbon and other atmospheric emissions. Calculated as GDP per unit of total energy supply. Source: OECD Green Growth indicators .	
Climate change mitigation technologies	CC mitigation	Number of environment-related inventions presented at patent offices for Climate Change mitigation technologies. Source: Patents: Technology development dataset (OECD) .	
Renewable energy generation	Renewable energy generation	Number of environment-related inventions presented at patent offices for renewable energy generation technologies. Source: Patents: Technology development dataset (OECD) .	
Climate change adaptation technologies	Adaptation technique	Number of environment-related inventions presented at patent offices for Climate Change adaptation technologies. Source: Patents: Technology development dataset (OECD) .	
Promotion of circular economy			
Municipal waste recycled or composted, % treated waste	Municipal waste recycled	Municipal waste recycled or composted is expressed as a percentage of all waste treated. Recycling is defined as any reprocessing of material in a production process that diverts it from the waste stream, except reuse as fuel. Both reprocessing as the same type of product, and for different purposes are included. Direct recycling within industrial plants at the place of generation is excluded. Composting is defined as a biological process that submits biodegradable waste to anaerobic or aerobic decomposition, and that results in a product that is recovered. Waste treated includes recycling, composting, incineration and landfill disposal. Source: OECD Green Growth indicators .	Argentina (ARG), Brazil (BRA), Bulgaria (BGR), Colombia (COL), Indonesia (IDN), New Zealand (NZL), Peru (PER), Romania (ROU), Thailand (THA)

Name	Short label	Description of the measure	Countries not covered
Reuse, recycling or recovery technologies	Recycling/recovery technique	Number of environment-related inventions presented at patent offices for Reuse, recycling or recovery technologies. Source: Patents: Technology development dataset (OECD) .	
Waste management	Waste management	Number of environment-related inventions presented at patent offices for waste management technologies. Source: Patents: Technology development dataset (OECD) .	
Incineration and energy recovery	Energy recovery	Number of environment-related inventions presented at patent offices for energy recovery technologies. Source: Patents: Technology development dataset (OECD) .	
Biodiversity protection			
Red list index	Red list index	An index between 0 and 1 showing trends in overall extinction risks for species. A higher RLI translates into lower extinction risk, while values closer to zero represent most species being in high risk. Source: OWID biodiversity indicators .	
Water resource management	Water resource management	Number of environment-related inventions presented at patent offices for water resource management technologies. Source: Patents: Technology development dataset (OECD) .	
Water pollution abatement	Water pollution abatement	Number of environment-related inventions presented at patent offices for water pollution reduction technologies. Source: Patents: Technology development dataset (OECD) .	
Wastewater treatment	Wastewater treatment	Number of environment-related inventions presented at patent offices for wastewater treatment technologies. Source: Patents: Technology development dataset (OECD) .	
Emission intensity			
Total CO2 emission intensity	CO2 (ln)	CO2 emission expressed in million tones per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
Total GHG emission intensity	GHG (ln)	Greenhouse gases refer to the sum of seven gases that have direct effects on climate change : carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3). Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
GHG from Agriculture (total) emission intensity	GHG- agriculture (ln)	GHG emission intensity from the agricultural sector. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
GHG from Energy industry (total) emission intensity	GHG - energy (ln)	GHG emission intensity from the energy production sector. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
GHG from Manufacturing and construction emission intensity	GHG - manufacturing (ln)	GHG emission intensity from the manufacturing and construction sectors. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)

Name	Short label	Description of the measure	Countries not covered
GHG from Transport emission intensity	GHG - transport (ln)	GHG emission intensity from the transport sector. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
GHG from Industrial processes and product use emission intensity	GHG- industrial processes (ln)	GHG emission intensity coming from industrial processes and product use. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)
GHG from waste emission intensity	GHG- waste (ln)	GHG emission intensity from waste. Expressed in thousand tons of CO2 equivalent per capita. Source: Air and GHG emissions database (OECD).	Thailand (THA)

Note: Full names, labels and detail for all environmental performance indicators used in panel estimations. Full coverage involves the 46 countries listed in Table A B.1. In case of panel regressions involving services trade as regressor of interest, the maximum period covered is 2005-2021. As for regressions involving the STRI, the maximum period covered is 2014-2021, and country coverage is of 42 countries excluding Argentina, Bulgaria, Croatia and Romania due to data availability. Some years might not be included for specific countries in certain variables due to data availability limitations.

Source: Green Growth indicators, IRENA, Patents: Technology Development database, Our World in Data.

Table A B.3. BaTIS sector classification of estimation sample

Chapter aggregation	Description
S	Total services
SA	Manufacturing services on physical inputs owned by others
SB	Maintenance and repair services n.i.e.
SC	Transport
SE	Construction
SF	Insurance and pension services
SG	Financial services
SH	Charges for the use of intellectual property n.i.e.
SI	Telecommunications, computer, and information services

Note: Sectoral classification categories used in the different econometrical estimations. This does not reflect the full coverage of the database, but rather only those included in the estimation samples of this document.

Source: The Balanced Trade in Services (BaTIS) database, OECD-WTO.

Table A B.4. STRI indicators

STRI label	STRI description
STRI_D	Digital sector, indicator STRI
STRI_CO	Construction sector, indicator STRI
STRI_CR	Courier sector, indicator STRI
STRI_CS	Computer sector, indicator STRI
STRI_DS	Distribution sector, indicator STRI
STRI_FSBK	Commercial banking sector, indicator STRI
STRI_FSINS	Insurance, indicator STRI
STRI_LSCAR	Logistics cargo-handling sector, indicator STRI
STRI_LSCUS	Logistics customs brokerage sector, indicator STRI
STRI_LSFGT	Logistics freight forwarding sector, indicator STRI
STRI_LSSTG	Logistics storage and warehouse, indicator STRI
STRI_PSACC	Accounting sector, indicator STRI
STRI_PSARC	Architecture sector, indicator STRI

STRI label	STRI description
STRI_PSENG	Engineering sector, indicator STRI
STRI_PSLEG	Legal sector, indicator STRI
STRI_TC	Telecom sector, indicator STRI
STRI_TRAIR	Air transport sector, indicator STRI
STRI_TRMAR	Maritime transport sector, indicator STRI
STRI_TRRAI	Rail freight transport sector, indicator STRI
STRI_TRROF	Road freight transport sector, indicator STRI

Note: Full names and labels for all the STRI index sectors used in estimations. Some sectors (including broadcasting, motion pictures, and sound recording) were omitted due to their low relevance in terms of environmental performance.

Source: OECD STRI Database.

Annex C. Supporting material for Section 3.2: The technique channel along manufacturing supply chains

This annex describes in detail the empirical strategy and data employed to identify the effect of lower policy barriers to upstream services imports on environmental performance in downstream manufacturing sectors discussed in Section 3.2. It also reports the main estimation results, details the quantification exercise, and the robustness checks.

Econometric framework

Empirical strategy

This econometric exercise consists of regressing CO2 intensity in production of downstream manufacturing sectors, measured as the ratio of emissions over gross output, on an indicator of trade restrictiveness of upstream services sectors (the treatment variable). The empirical strategy assumes the downstream effect of services trade policy to be a function of the intensity with which services are used as intermediate inputs by downstream manufacturing sectors. Therefore, the treatment variable is constructed by interacting country-sector services trade restrictiveness with a measure of services input use by downstream industries derived from input-output data. For any country i , year t , and downstream manufacturing sector j , a composite services trade restrictiveness indicator ($CSTRI$) is defined as follows:

$$CSTRI_{ijt} = \sum_s STRI_{ist} \times \omega_{js} \quad (2)$$

where s indexes services sectors. In the above equation, ω_{js} is defined as the percentage share of costs for intermediate service s in total output (production value) of manufacturing sector j .⁴⁰ To minimise the risk that services trade policy is endogenously determined by services input use, these weights are constant over time and across countries, reflecting services input use of a reference country, the US, in a pre-sample reference year, 2010.⁴¹ The baseline estimation regression is then:

$$y_{ijt} = \beta CSTRI_{ijt} + \gamma' X_{ijt} + \delta_{it} + \theta_{jt} + \lambda_{ij} + \varepsilon_{ijt} \quad (3)$$

where y is the dependent variable (CO2 intensity in production, in logs); X is a vector of control variables that include input tariffs, output tariffs, export share, import share and labor productivity (value added per employee); δ_{it} are country-time fixed effects; θ_{jt} are sector-time fixed effects; and λ_{ij} are country-sector fixed effects. The coefficient β is expected to be positive: because of the technique effect, higher services trade restrictiveness should deteriorate environmental performance, and therefore increases CO2 intensity in production, of downstream manufacturing industries.

⁴⁰ To maximise precision of the weights (ω_{js}) in capturing the technological relationships between sectors (rather than reflecting other forces including for example access to imports) the total cost shares are used which account for both foreign and domestically sourced inputs.

⁴¹ The choice of the United States as a reference country is common to the empirical literature that relies on similar composite indicators. The United States is multi-sector, diversified economy where I-O linkages are likely to be representative of the technological relationships between industries.

Identification

To identify a causal impact of upstream services trade restrictiveness on downstream manufacturing environmental performance, we must address two main potential sources of endogeneity: omitted variable bias and reverse causality. To minimize the risk of omitting variables that might be correlated with the regressor or interest and the outcome variable, we include the most restrictive set of fixed effects: country-time fixed effects, which control for observables and unobservables that vary across countries and over time (e.g. size, the level of economic development; preferences for environmental regulation); sector-time fixed effects, which control for any sector-specific characteristic or shock that varies over time (e.g. specificity of each industry's input mix); and country-sector fixed effects, which absorb any variation across country-sector pairs that could confound our relationship of interest (e.g. the geographical distribution of economic activity within countries).

The vector X includes other potential confounders varying at the country-sector-time level. These are: (a) output tariffs, defined as the applied tariff by country i in sector j in year t ; (b) input tariffs, defined for each manufacturing sector j in country i at time t as the weighted average tariff applied to manufacturing sectors different from j in country i at time t , with weights given by the input intensity coefficients ω ; (c) the log of value added per employee (a proxy for labor productivity) of manufacturing sector j in year t , country i in year t , (d) the share of gross exports of manufacturing sector j in total manufacturing exports of country i at time t , (e) the share of gross imports of manufacturing sector j in total manufacturing imports of country i at time t .

Reverse causality would arise if upstream services trade restrictiveness were endogenously determined by a sector's environmental performance. This could happen both if the overall level of services trade restrictiveness and if the intensity of services consumption had an impact on environmental performance. We adopt an approach that rules out the latter case, by using measures of intensity of services consumption that are sourced from the United States' input-output table in the pre-sample year 2010. The assumption is that the United States' I-O linkages are representative of the technological relationships between industries, and using pre-sample data for year 2010 further reduces the scope for reverse causality.

The use of United States' I-O data also helps reduce the scope of measurement error in the main explanatory variable. The United States is, in fact, a very diversified economy not only in terms of production of manufactured products (which assures representativeness across all covered downstream sectors), but also in terms of sourcing of services inputs, which reduces the scope for aberrant values of the technical coefficients that are multiplied with country-services sector measures of services trade liberalisation to construct the main explanatory variable, CSTR1.

Data

Emission intensity in production is sourced from the OECD Trade in Embodied CO2 Database (TECO2) database. Data are available for 66 countries and 17 manufacturing industries for the period 1995-2018. Services trade policy is measured through the OECD Services Trade Restrictiveness Index (STRI), which is available for 50 countries and 23 services sectors annually since 2014. Trade data as well as the technical coefficients are sourced from OECD TiVA, 2021 edition database. Merging STRI measures of services trade policy with TiVA data on services input intensity by the sectoral categories leads to a common list of 13 services sectors which are used to build the composite indicator $CSTR1_{ijt}$ as per Equation (2). These sectors and are listed in Table A C.1. Tariff data are sourced from the Harmonized WITS tariffs database.⁴² Value added per employee is sourced from the OECD Trade in Employment

⁴² The harmonized WITS tariffs database is an OECD inhouse tool that harmonizes work between United Nation's Comtrade and World Bank's TRAINS databases.

(TiM), 2023 edition database. The final sample comprises 49 countries (the full country coverage of the STRI database minus the US excluded from the sample to reduce endogeneity concerns) and 17 manufacturing industries, over the period 2014-2018 (sectors and countries in the estimation sample are listed in Table A C.2 and Table A C.3 respectively).

Table A C.1. Services classification

Chapter aggregation	Description	ISIC rev.4	STRI sector
E	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39	Computer services
F+G	Construction	41, 42, 43	Construction
	Wholesale and retail trade; repair of motor vehicles	45, 46, 47	Distribution
H	Land transport and transport via pipelines	49	Road freight transport
	Water transport	50	Maritime transport
	Air transport	51	Air transport
	Warehousing and support activities for transportation	52	Logistics
	Postal and courier activities	53	Courier services
J	Telecommunications	61	Telecommunications
	IT and other information services	62, 63	Computer services
K	Financial and insurance activities	64, 65, 66	Commercial banking and insurance services
M	Professional, scientific and technical activities	69 to 75	Accounting, architecture, engineering, and legal services
P	Education	85	Computer services

Source: Authors' elaboration using OECD TiVA edition 2021.

Table A C.2. List of manufacturing sectors in the estimation sample

TiVA code	Manufacturing industry
D10T12	Food products
D13T15	Textiles and apparel
D16	Wood
D17T18	Paper and printing
D19	Coke and petroleum
D20	Chemicals
D21	Pharmaceuticals
D22	Rubber and plastics
D23	Non-metal minerals
D24	Basic metals
D25	Fabricated metals
D26	ICT and electronics
D27	Electrical machinery
D28	Machinery
D29	Motor vehicles
D30	Other transport
D31T33	Other manufacturing

Note: This table includes only manufacturing sectors considered in the analysis.

Table A C.3. List of countries in the estimation sample

Country	Income level	Region code	Country	Income level	Region code
Australia (AUS)	HIC	EAS	Korea (KOR)	HIC	EAS
Austria (AUT)	HIC	EUR	<i>Latvia (LVA)</i>	HIC	EUR
Belgium (BEL)	HIC	EUR	<i>Lithuania (LTU)</i>	HIC	EUR
<i>Brazil (BRA)</i>	UMC	LCN	Luxembourg (LUX)	HIC	EUR
Canada (CAN)	HIC	NAC	<i>Malaysia (MYS)</i>	UMC	EAS
Chile (CHL)	HIC	LCN	Mexico (MEX)	UMC	LCN
<i>China (CHN)</i>	UMC	EAS	Netherlands (NLD)	HIC	EUR
Colombia (COL)	UMC	LCN	New Zealand (NZL)	HIC	EAS
Costa Rica (CRI)	UMC	LCN	Norway (NOR)	HIC	EUR
Czechia (CZE)	HIC	EUR	<i>Peru (PER)</i>	UMC	LCN
Denmark (DNK)	HIC	EUR	Poland (POL)	HIC	EUR
<i>Estonia (EST)</i>	HIC	EUR	Portugal (PRT)	HIC	EUR
Finland (FIN)	HIC	EUR	<i>Russia (RUS)</i>	UMC	CAS
France (FRA)	HIC	EUR	<i>Singapore (SGP)</i>	HIC	EAS
Germany (DEU)	HIC	EUR	Slovak Republic (SVK)	HIC	EUR
Greece (GRC)	HIC	EUR	Slovenia (SVN)	HIC	EUR
Hungary (HUN)	HIC	EUR	<i>South Africa (ZAF)</i>	UMC	SSF
Iceland (ISL)	HIC	EUR	Spain (ESP)	HIC	EUR
<i>India (IND)</i>	LMC	SAS	Sweden (SWE)	HIC	EUR
<i>Indonesia (IDN)</i>	UMC	EAS	Switzerland (CHE)	HIC	EUR
Ireland (IRL)	HIC	EUR	<i>Thailand (THA)</i>	UMC	EAS
Israel (ISR)	HIC	MEA	Türkiye (TUR)	UMC	CAS
Italy (ITA)	HIC	EUR	United Kingdom (GBR)	HIC	EUR
Japan (JPN)	HIC	EAS	<i>Viet Nam (VNM)</i>	LMC	EAS
<i>Kazakhstan (KAZ)</i>	UMC	CAS			

Note: OECD Members throughout the sample period (2014-2018) in bold. Latvia (OECD Member since 2016) and Lithuania (OECD Member since 2018) in italics. Income groups follow the World Bank classification (HIC = High-income; UMC = Upper-middle-income; LMC = Lower-middle-income). Geographical groups follow a slight modification of the World Bank classification (EAS = East Asia and Pacific; EUR = Europe; LCN = Latin America and Caribbean; NAC = North America; SAS = South Asia; MEA = Middle East and North Africa; CAS = Central Asia; SSF= Sub-Saharan Africa). The United States is excluded from the sample.

Estimation results

Table A C.4 presents the results of estimating Equation (3), adding controls one at a time. The estimated coefficient of *CSTRI* is positive and statistically significant across all estimations, showing that lower policy barriers to imports of services used as intermediate inputs reduce CO₂ emission intensity of manufacturing sectors downstream in the supply chain.

Table A C.4. Baseline estimation results (2014-2018)

Dependent variable: CO ₂ intensity in production	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CSTRI	43.47*** (16.43)	44.54** (18.60)	45.03** (18.59)	47.51*** (16.20)	44.35*** (16.45)	43.45*** (16.42)	47.19** (18.51)
Output tariff		0.18 (0.40)					0.36 (0.47)
Input tariff			-0.49 (0.50)				-0.73 (0.63)
Labor productivity				-0.06** (0.03)			-0.06** (0.03)
Export share					-0.88 (0.55)		-0.75 (0.62)
Import share						-0.44 (0.96)	-0.19 (0.95)
Observations	4,165	3,940	3,961	4,161	4,165	4,165	3,937
R-squared	0.98	0.98	0.98	0.98	0.98	0.98	0.98
f.e.	it ik kt	it ik kt	it ik kt	it ik kt	it ik kt	it ik kt	it ik kt
vce	robust	robust	robust	robust	robust	robust	robust
Number of countries	49	49	49	49	49	49	49
Number of sectors	17	17	17	17	17	17	17
Number of years	5	5	5	5	5	5	5

Note: *p<0.10, **p<0.05, ***p<0.01. Dependent variable: log of CO₂ intensity in production. Robust standard errors are reported in parentheses. Number of sectors: 17. Years included: 2014-2018. Country-time (it), (manufacturing) sector-time (jt) and country-sector (ij) fixed effects included in all estimations.

Source: Authors' elaboration.

Quantification exercise

The economic quantification of the estimation results is similar in spirit to (Beverelli, Fiorini and Hoekman, 2017_[61]), and is built according to the following steps.

- **Step 1:** For each *i-s* (country-services sector) combination, we compute the average of the four year-on-year change in STRI ($\overline{\Delta STRI}_{i,s}$).⁴³
- **Step 2:** Within each services sector *s*, the 25th percentile of the distribution of $\overline{\Delta STRI}_{i,s}$ from step 1 is computed. Denote this variable as $\Delta STRI(p25)_s$ which varies only across services sectors.
- **Step 3:** For each *i-s* combination, we compute the 'treatment', $\widehat{\Delta STRI}_{i,s}$, replacing the observed $\overline{\Delta STRI}_{i,s}$ with the counterfactual $\Delta STRI(p25)_s$ if the latter is smaller than the former, and setting

⁴³ $\overline{\Delta STRI}_{i,s} = \frac{1}{4} [(STR I_{2015} - STR I_{2014}) + (STR I_{2016} - STR I_{2015}) + (STR I_{2017} - STR I_{2016}) + (STR I_{2018} - STR I_{2017})]$. Note that these variables vary by country and services sector.

$\widehat{\Delta STRI}_{i,s} = \overline{\Delta STRI}_{i,s}$ otherwise.⁴⁴ That is, for those i - s combinations in which the factual liberalisation was larger than the counterfactual liberalisation, the liberalisation used in the quantification corresponds to the observed level, whereas for those combinations in which the factual liberalisation was smaller than the counterfactual liberalisation, the liberalisation used in the quantification corresponds to the counterfactual level.

- **Step 4:** For each country-service (i - s) combination, we compute $\sum_s \widehat{\Delta STRI}_{i,s} \times \omega_{js}$, where ω_{js} is the share of costs for intermediate services s in total output (production value) of manufacturing sector j , as introduced in Equation (2).

Then, the estimated percentage change in CO2 intensity of manufacturing sector j resulting from i 's reform scenario is given by:

$$\% \Delta Y_{ij} = 100 \times \hat{\beta} \times \left(\sum_s \widehat{\Delta STRI}_{i,s} \times \omega_{js} \right) \quad (4)$$

where Y_{ij} is CO2 emission intensity without the log transformation and $\hat{\beta}$ is the estimated coefficient of CSTRI from column (1) of Table A C.4. Table A C.5 provides observed descriptive statistics of main variables included in the estimations across 49 countries and 17 sectors for the period 2014-2018. Table A C.6 provides descriptive statistics for the 833 estimated counterfactual percentage changes in CO2 emission intensity estimated by country and sector.⁴⁵ All the estimated changes are negative (implying a reduction in CO2 emissions intensities), with an average of -1.5 and a median of -1.

Table A C.5. Descriptive statistics for variables of the estimations

Variable	Mean	Median	Std dev	Min	Max
CO ₂ intensity in production	3.64	3.42	1.76	-5.81	12.19
STR _{it}	0.04	0.04	0.02	0.01	0.16
Output tariff	0.02	0.01	0.04	0	0.45
Input tariff	0.00	0.00	0.01	0	0.27
Labor productivity	10.85	10.99	1.50	0	18.51
Export share	0.06	0.03	0.08	0	0.77
Import share	0.06	0.05	0.04	0.00	0.42

Note: This table displays descriptive statistics of main variables included in the estimations. The perimeter of the sample includes 17 sectors for the period 2014-2018. CO₂ intensity in production is expressed in tonnes of CO₂ per millions of US dollars.

Source: Authors' computation.

⁴⁴ The variable $\Delta STRI_{25}$ is always non-positive. Therefore, when the factual $\Delta STRI_{avg}$ is negative, but larger (i.e. closer to zero) than the counterfactual $\Delta STRI_{25}$, we replace a negative number with a more negative (i.e. smaller) number.

⁴⁵ $N = 833 = 49$ countries \times 17 sectors.

Table A C.6. Descriptive statistics for percentage change in emission intensity

Mean	10 th percentile	Median	90 th percentile	Std Dev	Min	Max
-1.51	-3.10	-0.99	-0.70	1.33	-8.88	-0.50

Note: This table displays percentage change in CO₂ intensity of manufacturing sector *j* in country *i*.

Source: Authors' elaboration.

Table A C.7. provides aggregate results by country. In particular, the 833 estimated counterfactual percentage changes in CO₂ emissions intensity are aggregated across manufacturing sectors within each country in three different ways: in column (1), there is the simple average across the 17 manufacturing sectors; in column (2), a sector characterised by high emission intensity and long length of the supply chain on average across countries is selected, i.e. Rubber and plastics products (C22); in column (3), the sector with highest overall levels of CO₂ emissions on average across countries is selected, i.e. Basic metals (C24).

Results of Table A C.7. are heterogeneous across countries, but largely independent on how they are aggregated across sectors within each country. Across countries with at least one 'treated' sector, the largest counterfactual reductions in manufacturing CO₂ intensity are estimated for East Asian countries such as Thailand, Viet Nam, Korea, and Indonesia.⁴⁶ Conversely, European countries with at least one 'treated' sector, such as Estonia, France, and Sweden generally experience small counterfactual reductions.⁴⁷

Table A C.7. The estimated effect of services trade reforms on CO₂ emission intensity for specific supply chains

Country (ISO)	Estimated % change in CO ₂ intensity			STRI in 2014	Average observed % change in STRI	Treated sectors
	Average across manufacturing	D22: Rubber and plastics products	D24: Basic metals			
Australia (AUS)	-2.66	-2.92	-2.79	0.21	-1.58	0/13 = 0%
Austria (AUT)	-0.82	-0.83	-0.82	0.22	0.12	11/12 = 91.6%
Belgium (BEL)	-1.01	-0.98	-1.14	0.25	-0.10	11/13 = 84.6%
Brazil (BRA)	-1.70	-1.79	-2.25	0.30	-1.95	4/13 = 30.7%
Canada (CAN)	-0.89	-0.90	-0.92	0.22	-0.26	11/13 = 84.6%
Chile (CHL)	-1.50	-1.70	-1.37	0.17	-0.38	10/13 = 76.9%
China (CHN)	-1.03	-0.99	-1.25	0.36	1.27	10/13 = 76.9%
Colombia (COL)	-1.55	-1.39	-1.63	0.19	-0.45	6/13 = 46.1%
Costa Rica (CRI)	-1.62	-1.91	-1.41	0.20	-0.16	11/13 = 84.6%
Czechia (CZE)	-0.93	-0.96	-0.90	0.14	1.04	11/12 = 91.6%
Denmark (DNK)	-0.83	-0.84	-0.84	0.17	1.72	13/13 = 100%
Estonia (EST)	-1.41	-1.30	-2.55	0.22	-2.23	3/13 = 23.0%
Finland (FIN)	-2.37	-2.64	-2.36	0.23	-1.32	4/13 = 30.7%
France (FRA)	-0.94	-0.93	-0.93	0.21	-0.12	6/13 = 46.1%
Germany (DEU)	-0.83	-0.84	-0.84	0.15	0.04	12/13 = 92.3%
Greece (GRC)	-0.84	-0.84	-0.85	0.27	0.10	10/13 = 76.9%
Hungary (HUN)	-0.82	-0.83	-0.82	0.19	4.57	12/12 = 100%
Iceland (ISL)	-1.00	-0.97	-1.13	0.38	0.49	10/13 = 76.9%

⁴⁶ Japan is an exception to this pattern, with smaller estimated counterfactual reductions in CO₂ intensity.

⁴⁷ Portugal and, to a lesser extent, Finland are exceptions, with large estimated counterfactual reductions in CO₂ intensity.

Country (ISO)	Estimated % change in CO2 intensity			STRI in 2014	Average observed % change in STRI	Treated sectors
	Average across manufacturing	D22: Rubber and plastics products	D24: Basic metals			
India (IND)	-0.99	-1.00	-1.12	0.39	0.48	10/13 = 76.9%
Indonesia (IDN)	-3.58	-4.29	-3.55	0.45	-1.06	5/13 = 38.4%
Ireland (IRL)	-0.83	-0.84	-0.84	0.18	-0.04	12/13 = 92.3%
Israel (ISR)	-1.39	-1.37	-1.41	0.31	-0.64	9/13 = 69.2%
Italy (ITA)	-0.83	-0.84	-0.84	0.24	0.11	12/13 = 92.3%
Japan (JPN)	-0.95	-0.93	-1.08	0.17	-0.10	9/13 = 69.2%
Kazakhstan (KAZ)	-1.62	-1.25	-1.99	0.43	-3.75	4/13 = 30.7%
Korea (KOR)	-3.65	-4.18	-3.44	0.31	-0.99	3/13 = 23.0%
Latvia (LVA)	-0.83	-0.84	-0.84	0.17	0.31	12/13 = 92.3%
Lithuania (LTU)	-0.83	-0.84	-0.84	0.17	2.78	13/13 = 100%
Luxembourg (LUX)	-0.82	-0.83	-0.82	0.21	0.26	11/12 = 91.6%
Malaysia (MYS)	-0.83	-0.84	-0.84	0.32	0.03	12/13 = 92.3%
Mexico (MEX)	-1.17	-1.22	-1.23	0.30	-0.07	10/13 = 76.9%
Netherlands (NLD)	-1.66	-1.94	-1.50	0.15	-0.19	10/13 = 76.9%
New Zealand (NZL)	-0.83	-0.84	-0.84	0.19	1.43	13/13 = 100%
Norway (NOR)	-1.10	-1.00	-1.19	0.27	-1.13	7/13 = 53.8%
Peru (PER)	-0.86	-0.88	-0.86	0.23	-0.16	11/13 = 84.6%
Poland (POL)	-0.83	-0.84	-0.84	0.20	1.12	13/13 = 100%
Portugal (PRT)	-5.01	-5.77	-5.47	0.21	-2.70	1/13 = 7.6%
Russia (RUS)	-0.83	-0.84	-0.84	0.39	1.14	13/13 = 100%
Singapore (SGP)	-2.53	-2.33	-2.13	0.25	-0.66	8/13 = 61.5%
Slovak Republic (SVK)	-0.82	-0.83	-0.82	0.18	-0.05	10/12 = 83.3%
Slovenia (SVN)	-0.83	-0.84	-0.84	0.23	0.94	12/13 = 92.3%
South Africa (ZAF)	-0.83	-0.84	-0.84	0.23	3.58	13/13 = 100%
Spain (ESP)	-0.88	-0.88	-0.91	0.15	-0.33	10/13 = 76.9%
Sweden (SWE)	-1.55	-1.63	-1.72	0.24	-1.11	1/13 = 7.6%
Switzerland (CHE)	-0.82	-0.83	-0.82	0.26	0.00	11/12 = 91.6%
Thailand (THA)	-6.09	-6.98	-5.91	0.46	-1.42	1/13 = 7.6%
Türkiye (TUR)	-0.83	-0.84	-0.84	0.27	3.36	13/13 = 100%
United Kingdom (GBR)	-0.83	-0.84	-0.84	0.17	1.60	13/13 = 100%
Viet Nam (VNM)	-5.64	-7.19	-4.60	0.35	-0.35	8/13 = 61.5%

Note: The table displays in turn: (i) the average manufacturing sectors or the value for Sector D22 (Rubber and plastics products), (ii) the value for sector D24 (Basic metals) of estimated % change in emission intensity, defined in Equation (4), (iii) $STRI_{2014}$ is the average level of STRI across services sectors in country i in the initial year (2014), (iv) % change in STRI observed between 2014 and 2018, averaged across services sectors in country i , (v) the observed % change in emissions intensity between 2014 and 2018 averaged across services sectors in country i , (vi) treated sectors which correspond to the number and the share of sectors in which the factual liberalisation in STRI was smaller than the counterfactual liberalisation in STRI in country i .

Source: Authors' elaboration.

Table A C.8. shows conditional correlations between the estimated change in emission intensity ($\% \Delta Y_{ij}$) and: (i) the country-sector initial level of CO₂ emission intensity (in year 2014); (ii) the country-level initial level of STRI (averaged across services sectors in year 2014) and (iii) the 2014 level of GDP per capita of country *i* (in logs). The table provides suggestive evidence that the counterfactual emission intensity reductions are larger in sectors with higher initial CO₂ emission intensity, and in countries with initial higher level of services trade restrictiveness and initial lower levels of development.

Table A C.8. Correlates of the percentage change of emission intensity

	(1)	(2)	(3)
Log CO ₂ int. 2014	0.022*		
	(0.013)		
STRI 2014		6.607***	
		(0.744)	
Log GDP p.c. 2014			-0.409***
			(0.064)
Observations	833	833	833
Fixed effects	ij	j	j

Note: $p < 0.10$, $**p < 0.05$, $***p < 0.01$. Dependent variable: absolute value of $\% \Delta Y_{ij}$ ($\% \Delta Y_{ij}$ defined in equation (3)). Log CO₂ int. 2014 is the CO₂ production emission intensity in sector *j* in country *i* in 2014. STRI 2014 is the level of STRI in 2014, averaged across services sectors *s* in each country *i*. Log GDP p.c. 2014 is the log of GDP per capita in country *i* in 2014 (sourced from IMF's World Economic Outlook Database, April 2024). Robust standard errors in parentheses. Number of countries: 49. Number of sectors: 17

Source: Authors' elaboration.

Robustness tests

As argued in Section 3.1, reverse causality is unlikely to be significant source of bias, due to the fact that we use quasi-exogenous weights in measuring CSTRI, and also because, by construction, the policy variables apply to (upstream) services rather than to (downstream) manufacturing. An instrumental variable strategy similar to the one proposed by (Beverelli, Fiorini and Hoekman, 2017_[61]) in a cross-sectional framework failed to deliver significant results in this richer framework (where identification is within country-sectors over time), due to a weak instruments problem. However, as a way of reducing reverse causality concerns, we re-estimated model 2 using the first lag of CSTRI as explanatory variable, and we still obtain a positive and significant effect of CSTRI – see column (1) of Table A C.9.

In column (2) of Table A C.9, the baseline model with two-way clustered fixed effects (Cameron et al., 2011) is estimated, by country and sector. This allows for autocorrelation of the errors within countries and sectors. The coefficient of interest is less precisely estimated but remains statistically significant at the 10% level.

To verify that the results are not driven by any particular country or industry, the baseline model of column (1) of Table A C.4 is estimated dropping each country or each industry at the time.⁴⁸

⁴⁸ Results of estimations that drop one country and one industry at the time ($49 \times 17 = 833$ regressions) are also all in line with baseline estimations and are available upon request.

Table A C.9. Robustness checks

Dependent variable	(1)	(2)
CSTR I _{t-1}	24.83*	
	(14.75)	
CSTR I _t		43.47*
		(23.51)
Observations	3,332	4,165
R-squared	0.99	0.98
f.e.	it ik kt	it ik kt
vce	robust	cluster i k
Number of countries	49	49
Number of sectors	17	17
Number of years	4	5

Note: Dependent variable: log of CO2 intensity in production. Number of observations: 4,165. Number of countries: 49. Number of sectors: 17. Years included: 2014-2018.

Source: Authors' elaboration.

Annex D. Supporting material for Section 4.1: Does environmental policy promote the use of international services?

Data

For all empirical exercises discussed in Section 4.1, we base our estimations on two main databases already introduced in previous sections of the paper: CAPMF (Section 4) and BaTIS (Section 3.1). From the CAPMF database we source measures of environmental policy stringency. The database provides indicators taking values from 0 to 10 that measure the level of stringency in a given environmental policy dimension, with 0 representing very low or no stringency, and 10 its maximum level. The database covers the period between 1990 and 2022, and indicators are available for 50 different countries. While the data has up to four categories or “levels” of variables depending on the level of aggregation, data availability decreases with less aggregated indicators. In this study we focus on the most aggregate level, level 1 and an aggregation by “policy types”, which holds the same complexity level as level 2 on the original framework.

Level 1 has three variables, determining policy stringency of sectoral, cross-sectoral and internationally oriented policies. These variables are all available for all countries and years in the database. An unweighted average of the three is the closest measure of a country-level average stringency, which is used for some of the estimations. Policy type indicators provide a more disaggregated detail. Contrary to the “benchmark” aggregation proposed in the database, they focus on the stringency level by policy instrument types rather than the areas affected (Table A D.1). These are the variables used for most estimations, given level 2 (or its policy type equivalent) is the largest level of detail at which most of the variables are available for all countries and years.

From the BaTIS database, we take the services trade data used in all estimations. BaTIS provides yearly values for services trade in current USD. The data is available for total services trade as well as for 12 services categories. Estimates of internal trade which are not included in BaTIS are built from the OECD STAN database. The national accounts data from STAN provides information on services production at the level of ISIC Rev.4 sectoral categories. We establish a correspondence between the services sectors in the two datasets. It must be noted, however, that the correspondence is not perfect, and therefore we can only provide internal trade estimates for 6 out of the 12 sectors in BaTIS.

As an additional source, the ITPD-E database is also used for the estimations corresponding to the “Other business services” sector. In ITPD-E, international trade in services data is drawn from the WTO-UNCTAD-ITC Annual Trade in Services Database and the UN Trade in Services Database (Comtrade). This database already includes internal trade estimates, using production data from the UN National Accounts database. Similarly to BaTIS, the internal trade matching also forces to exclude certain sectors that would be available for international trade only. The main difference between the two databases lies in the different availability of sectoral data. While some sectors are shared, BaTIS includes sectors such as Maintenance and Repair services, which ITPD-E does not (and is a very large category). On the other hand, ITPD-E includes certain categories that BaTIS does not, such as other business services, which is why we rely on it for the estimation of this sector. It could also be useful as an additional robustness check for the results of the sectors that coincide with BaTIS, left for future research.

Finally, for certain estimations some additional controls are required. The CEPIL gravity database is used for data regarding controls such as the FTA variable included in all our estimations. Additionally, variables such as GDP or GDP per capita are also used in the estimations of the marginal effect on services trade, as controls for country-time varying variables. Other additional sources are Our World in Data for manufacturing value added as a share of GDP and UNCTAD for inward FDI flows.

Table A D.1. CAPMF indicators

CAPMF Policy type variable	Policy examples
Taxes and fees	Carbon taxes Fossil fuel subsidy reforms Fossil fuel excise taxes
Trading systems	Renewable energy certificates ETS Emission pricing
Subsidies	Feed in tariffs Renewable energy auctions Financing mechanisms RD&D expenditure
Performance standards	Air emission standards MEPS Building energy codes
Technology standards	Ban and phase outs on fossil fuels (use, support, production expansions)
Information instruments	Mandatory energy labels for appliances Labels for vehicles
Other non-market-based instruments	Planning for renewables expansion Energy efficiency mandates Speed limits on motorways Methane abatement policies Share of rail on transport public expenditure
Targets	Nationally determined contributions Net Zero targets
International co-ordination	Ratification of key international climate treaties Participation in international climate initiatives
Climate governance	Climate advisory bodies
Climate data	Evaluation of biennial reports Submission of key UNFCCC documents GHG emissions reporting and accounting

Source: CAPMF, OECD.

Gravity with internal trade: Econometric specification and estimation sample

The structural gravity equation augmented with domestic services trade flows is used in the paper to estimate the linkages between measures of bilateral services trade and environmental policy. It is an extension of the gravity model (Salette and Tinbergen, 1965^[62]) that, accounting for the latest developments in the literature in terms of identification strategy and structural interpretation of the estimated parameters (Anderson and van Wincoop, 2003^[63]; Head and Mayer, 2014^[64]), allows to gain insights on the trade effects of variables that vary only at the level of a single trade partner. In particular, all our specifications of the panel gravity framework include exporter-time and importer-time fixed effects, which allow to control for multilateral resistance terms and any observed and unobserved country-specific covariates that may vary across time (productivity shocks, exchange rate fluctuations, terms of trade changes) (Baier, Yotov and Zylkin, 2019^[65]). Additionally, we also introduce country-pair fixed effects. This allows to control for all time-invariant bilateral explanatory variables normally included in gravity analysis (distance, common language, common border, etc.). Including country-pair fixed effects allows to identify the coefficients in the gravity specification using only variation over time and within country pairs. Moreover, this approach controls for endogeneity of policies depending on bilateral relationships, allowing for a more robust causal interpretation of the coefficients (Baier and Bergstrand, 2007^[66]).

However, in a standard structural gravity framework with the three-way fixed effects as described above it would be impossible to estimate the coefficient that corresponds to environmental policy stringency. If included directly into the equation, such variable would be perfectly collinear with the importer-time fixed effects, and its coefficient would not be identified. The extension of the panel gravity setting with the inclusion of internal trade flows allows to solve this problem. More precisely, adding internal trade flows allows to define an international border (IB) dummy variable, that takes value 1 when trade is international, i.e. when it happens between two countries separated by an international border. The IB dummy can then be interacted with the measure of domestic environmental policy stringency, which is country-year specific. This interaction term instead varies at the importer-exporter-time level and is not absorbed by the three-way fixed effects. Its coefficient can therefore be estimated, allowing to identify the differential effect of environmental policy stringency on international trade in services with respect to domestic flows.

Our estimation of the panel gravity equation with internal trade is based on the Poisson Pseudo Maximum Likelihood (PPML) technique introduced by (Santos Silva and Tenreyro, 2006^[46]). This is the common approach for the estimation of gravity models, as it allows retaining zeros in trade data due to its functional form, as well as being robust to different patterns of heteroscedasticity. The estimating specification is given by the following equation:

$$EXP_{ijt} = \exp(\beta CAPMF_{jt} BD_{ij} + \gamma FTA_{ijt} + \varphi_{it} + \delta_{jt} + \theta_{ij}) + \varepsilon_{ijt} \quad (5)$$

where EXP_{ijt} represents services exports from exporter i to importer j at time t . $CAPMF_{jt}$ is a CAPMF indicator measuring environmental policy stringency in the importer country j on a given year. BD_{ij} is the international border dummy, which is country-pair specific. FTA_{ijt} is a dummy that takes value 1 when there is a trade agreement in place between the two countries at a given year. This is a bilateral, time-varying covariate that can affect simultaneously trade and environmental policy.⁴⁹ φ_{it} , δ_{jt} and θ_{ij} are exporter-time, importer-time, and country-pair fixed effects, respectively. Following (Egger and Tarlea, 2015^[67]) and (Larch et al., 2019^[68]), errors are clustered by country pair and year, to avoid for potential autocorrelation of standard errors across all three dimensions of the panel.

⁴⁹ In their recent review Copeland, Shapiro and Scott Taylor (2022^[3]) discuss how environmental policy can substitute trade policy measures such as import tariffs when the latter are reduced or eliminated by trade agreements.

We use the specification in Equation (5) to estimate 96 regressions, each of them defined by a combination of the 7 sectoral categories in the BaTIS-STAN services trade database with internal flows, with the addition of the other business services sector from ITPD-E, and the 12 CAPMF indicators (all 11 policy type variables and the aggregate indicator). The estimation sample consists of 73,474 observations, covering 38 importing countries for which CAPMF indicators of environmental policy are observed, up to 229 exporting countries, for the period 2005-2021. For other business services, given the use of ITPD-E database, the coverage is slightly different: 49,331 observations, coming from a lower amount of exporting countries covered (209) for the period 2000-2021. Table A.D.2 provides summary statistics for the main variables in the estimation sample.

Table A.D.2. Summary statistics of key variables

Variable	Source	Mean	Median	Standard Dev.	Min	Max
Total exports (including domestic trade)	BaTIS and STAN	5277.58	0	234322.77	0.00	26553593
FTA	CEPII	0.29	0.00	0.45	0.00	1.00
CAPMF Average	CAPMF	2.82	2.53	1.40	0.39	6.96
Subsidies	CAPMF	3.10	3.00	2.37	0.00	7.90
Trading systems	CAPMF	1.99	2.00	1.43	0.00	7.56
Taxes and fees	CAPMF	2.51	2.83	1.63	0.00	5.96
Tech. Standards	CAPMF	0.44	0.00	0.88	0.00	5.50
Other NMBI	CAPMF	2.85	2.60	1.73	0.00	7.60
Performance standards	CAPMF	5.52	5.90	2.79	0.00	10.00
Information instruments	CAPMF	7.68	8.75	3.16	0.00	10.00
Targets	CAPMF	1.96	0.00	3.02	0.00	9.00
Climate governance	CAPMF	1.08	0.00	2.37	0.00	9.80
International co-ordination	CAPMF	5.00	3.83	2.38	0.00	10.00
Climate data	CAPMF	3.66	3.00	2.55	0.00	9.50

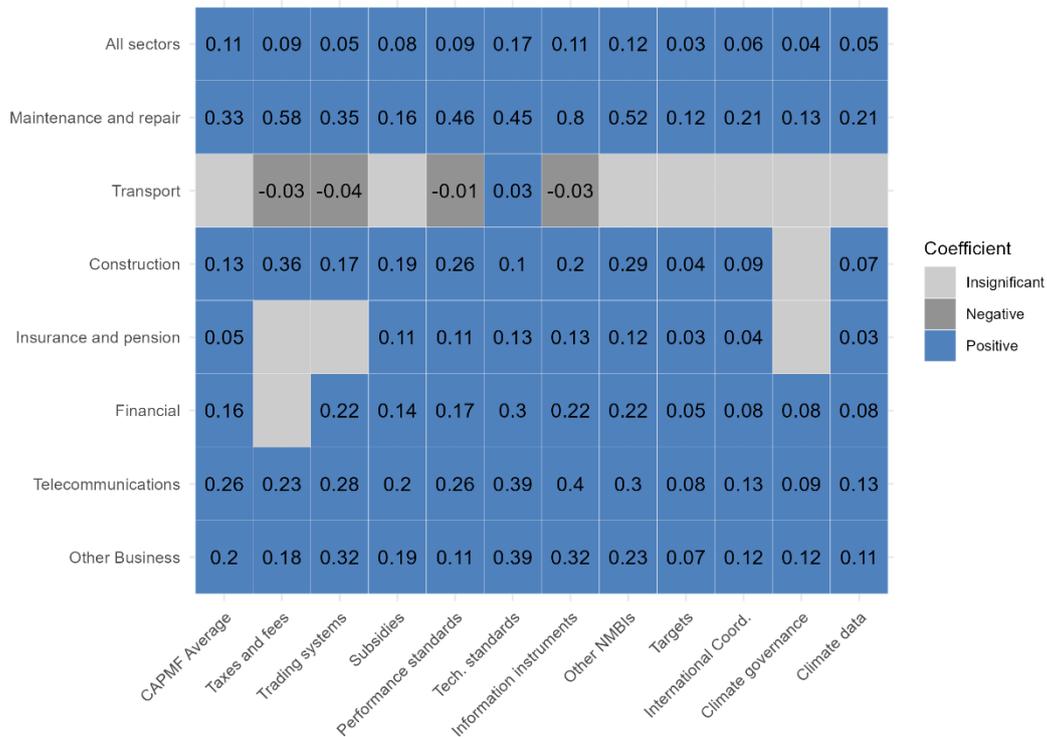
Note: This table includes the main descriptive statistics for all variables used in the augmented gravity framework exercise. The estimation sample consists of 73 474 observations, covering 38 importing countries for which CAPMF indicators of environmental policy are observed, 229 exporting countries, for the period 2005-2021. Exports include internal trade (production) values needed for the estimation. Exports and production are expressed in current USD. FTA is a dummy variable and the CAPMF variables are expressed on a 1 to 10 scale, where 0 (10) indicates minimum (maximum) environmental policy stringency. Trade data typically includes a high number of zeros, which explains the relatively low values of the mean and median with respect to the SD.

Source: BaTIS, CAPMF, STAN and CEPII.

Estimation results

Results from the 96 gravity regressions for CAPMF policy types are summarized in Figure A D.1, where each cell of the matrix shows, for a given sector and CAPMF variable, the value of $\hat{\beta}$, i.e. the estimated coefficient of the interaction between environmental policy stringency and the international border dummy from equation (6).

Figure A D.1. Estimated differential effect of CAPMF indicators on services imports with respect to domestic sourcing



Note: Each cell of the matrix in the figure shows, for a given sector and CAPMF variable, the estimated coefficient of the interaction between environmental policy stringency and the international border dummy from the regression including trade in the specified services sector as dependent variable and using the selected CAPMF indicator as the measure of environmental policy stringency. Colour codes identify statistically significant (at least at the 95% confidence level) positive (blue) and negative (dark grey) estimates, as well as estimates that do not meet that significance level of 95% (light grey). These estimates are interpreted as the differential effect of environmental policy stringency, as captured by CAPMF indicators, on services imports in a specific sectoral category, with respect to domestic sourcing of the same services.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

For illustrative purposes, Table A D.3 displays more detailed estimation results from the gravity equation with total services imports (covering all sectors) as dependent variable and the CAPMF indicator in for climate governance policies as measure of environmental policy stringency. The estimated coefficient for the interaction between environmental policy stringency and the international border dummy is positive and statistically significant at the 99% confidence level. As all the other estimated coefficients presented in Figure A D.1, it can be interpreted roughly as a semi-elasticity. More precisely, the estimated coefficient equal to 0.0417 reported in Table A D.3 implies that a one unit increase in the indicator of environmental policy stringency in the area of climate governance (corresponding to roughly half of a sample standard deviation) is associated to a change in total services imports which is $100(e^{0.0417} - 1) = 4.3$ percentage points higher than the change in domestic sourcing. Assuming for example that the environmental policies determining a one unit increase in the CAPMF indicator on climate governance would lead to an increase of 1% in domestic services performed for domestic demand, then the increase in services imports associated to the same policies would be of $1 + 4.3 = 5.3\%$.

Table A D.3. Example PPML regression: All services trade on Climate governance

Dependent variable	All sectors
Int Border X Climate Governance	0.0417*** (0.00477)
FTA	0.169*** (0.0309)
Constant	15.11*** (0.00140)
Observations	73 474
Country-pair FEs	Yes
Importer-time Fes	Yes
Exporter-Time Fes	Yes

Note: The coefficient of interest should be interpreted as the differential effect with respect to internal trade. Robust standard errors clustered by exporter-importer-time are reported in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and CEPIL.

Plug-in LASSO and iceberg LASSO

The two-step LASSO framework introduced in Section 4.1.2 and used to determine the policy variables relevant to our setting follows the methodology of Breinlich et al. (2021_[48]).

First step: Plug-in LASSO

The 'plug-in' LASSO approach consists of running the same PPML regression used for first estimations but adding a LASSO penalty term to it. This penalty is applied to a set of 11 variables of interest, giving more weight to the coefficients of those with a better predictive power and giving a higher penalty to coefficients of variables with little predictive power. The LASSO algorithm will then leave aside those variables with too high penalties, keeping only those that have low penalty values. It is important to note that fixed effects coefficients are exempt from the penalty, so they will always be present in the regression.

The key difference between plug-in LASSO and other similar methodologies consists of a penalty chosen following statistical theory (Belloni et al., 2016_[49]). Intuitively, what this procedure does is to set the coefficient of each of the variables to zero, and to assign the penalty based on how much the fit of the model improves without that variable. This approach differs from choosing the penalty parameters based on cross-validation. According to that methodology penalties are determined by predictive power on a within-sample calibration.⁵⁰ Breinlich et al. (2021_[48]) show that the plug-in LASSO tends to be more parsimonious and restrictive, resulting in less variables being selected.

After the plug-in LASSO procedure, a second estimation (post-LASSO) is performed by fitting the PPML services trade regressions only with the interactions selected by the plug-in LASSO. Table A D.4 shows the post-LASSO estimated coefficients for the selected interaction terms featuring a CAPMF indicator (listed in the row-dimension of the table) in each regression associated to a specific sectoral category of services trade (listed as column of the table).

⁵⁰ While this allows for the penalty to vary according to the sample quality, it also tends to be very permissive, selecting a large percentage of the variables.

Table A D.4. Differential effect of those CAPMF indicators selected by the plug-in LASSO

Variable	All sectors	Maintenance and repair	Transport	Construction	Insurance and pension services	Financial	Telecommunications	Other Business
Taxes and fees								0.014
								(0.029)
Trading systems						-0.003		0.153***
						(0.027)		(0.026)
Subsidies						0.074***		0.016
						(0.027)		(0.019)
Performance standards	0.049***	0.263***		0.211***		0.071***	0.137***	0.015
	(0.015)	(0.037)		(0.059)		(0.025)	(0.023)	(0.019)
Tech. standards						0.147***		
						(0.047)		
Information instruments	-0.007						0.068***	0.145***
	(0.013)						(0.025)	(0.032)
Other NMBIs	0.018	0.034		0.102*		0.088***		0.010
	(0.012)	(0.052)		(0.058)		(0.027)		(0.030)
Targets								
International Coord.	0.031***	0.112***					0.067***	0.015
	(0.007)	(0.025)					(0.012)	(0.011)
Climate governance								
Climate data								

Note: This table shows the results of 8 different post-LASSO regressions, one per sectoral category of services trade. Coefficients estimated only for the interaction terms selected by the plug-in LASSO procedure. Standard errors are shown in parenthesis. The estimation sample for each of these eight regressions is the same as in the corresponding regression with only one interaction.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

The maximum number of interaction terms selected as relevant by plug-in LASSO is seven (for other business services). None of the interaction terms is selected as a relevant predictor for trade in transport nor insurance and pension services, confirming and strengthening the results of the initial estimations where most of the CAPMF indicators did not show any statistically significant differential effect on imports of transport services (Figure A D.1) while also revealing that the initial estimates for insurance and pension services could have been affected by omitted variable bias. Interactions featuring the following 2 CAPMF variables are never selected: policies regarding climate data policies and policies in the area of climate governance.

Second step: Iceberg LASSO

The second step is the 'iceberg LASSO'. It consists in running a LASSO regression for each CAPMF indicator whose corresponding interaction with the IB dummy was selected by the plug-in LASSO. All the CAPMF indicators featuring in the interaction terms that were not selected by the plug-in LASSO are included on the right-hand side of these new iceberg LASSO regressions. Those variables retained by the iceberg LASSO estimations, are likely to have a similar explanatory power as the ones captured by the plug-in LASSO. Therefore, we cannot claim that these variables do not exert any differential effect on services trade. Table A D.5 reports the results from the iceberg LASSO applied to the CAPMF indicators included in the interaction terms selected by the plug-in LASSO regression for total services trade.

Table A D.5. Iceberg LASSO-Selected Variables

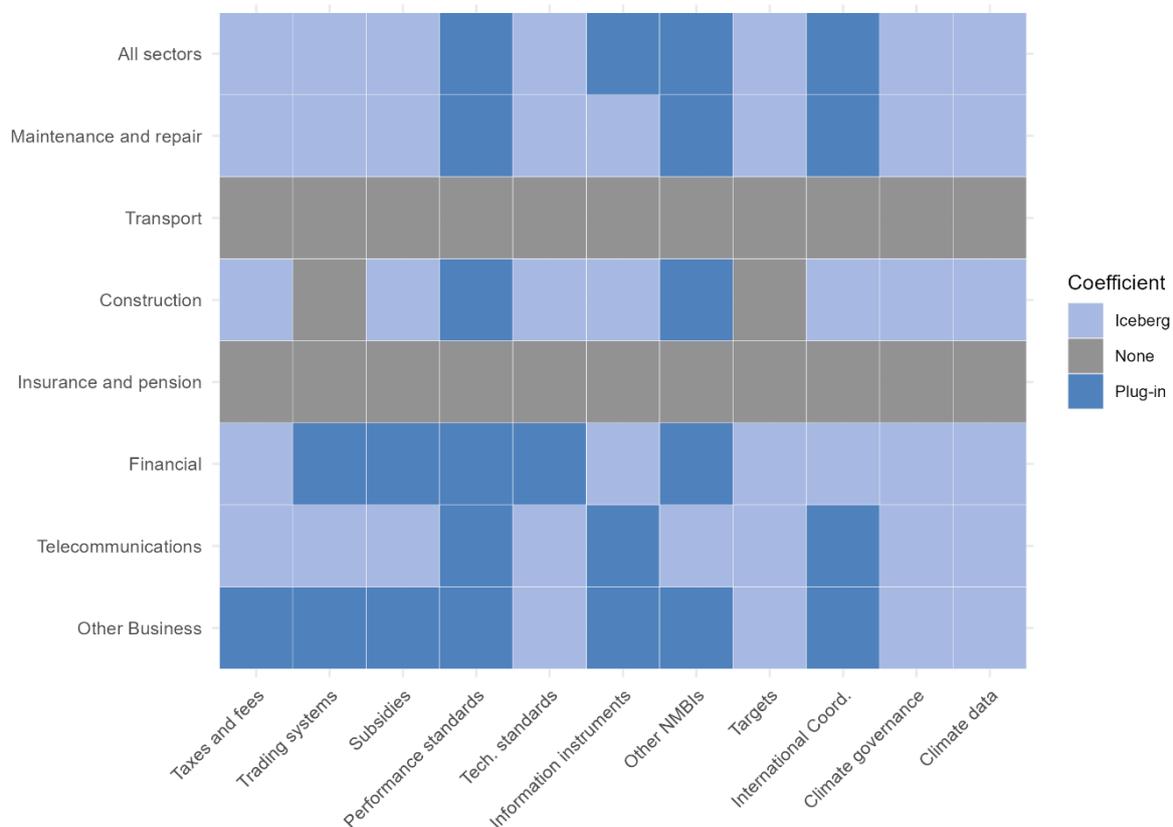
Variables selected by plug-in LASSO in the gravity specification for total services trade				
	Performance standards	Information instruments	Other NMBI	International Co-ordination
Variables selected by iceberg LASSO	Taxes and fees (0.67)	Taxes and fees (0.35)	Taxes and fees (0.58)	Taxes and fees (0.55)
	Subsidies (0.66)	Trading systems (0.44)	Trading systems (0.32)	Trading systems (0.46)
	Tech. standards (0.33)	Subsidies (0.38)	Subsidies (0.66)	Subsidies (0.37)
	Targets (0.48)	Tech. standards (0.13)	Tech. standards (0.32)	Tech. standards (0.68)
	Climate governance (0.22)	Targets (0.19)	Targets (0.42)	Targets (0.88)
	Climate data (0.71)	Climate governance (0.16)	Climate governance (0.34)	Climate governance (0.39)
		Climate data (0.50)	Climate data (0.43)	Climate data (0.72)

Note: CAPMF indicators listed in bold on top of each column are those included in the interaction terms selected by the plug-in LASSO regression for total services trade. Below each of these five variables, the table reports the CAPMF indicators selected by the iceberg LASSO. Correlations between the CAPMF indicator selected through plug-in LASSO and the associated indicators selected by iceberg LASSO are reported in parenthesis.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and CEPII.

Figure A D.2 summarises the results of the two-step algorithm employed to identify relevant dimensions of environmental policy stringency. The heatmap in Figure A D.2 indicates, for each sectoral category of services trade (listed across the rows of the matrix), if a CAPMF indicator (listed across the columns of the matrix) is selected as relevant by the plug-in LASSO estimation (dark blue), the iceberg LASSO (light blue), or by none of them (grey).

Figure A D.2. Relevant dimensions of environmental policy stringency across sectoral categories of services trade



Note: The heatmap indicates, for each sectoral category of services trade (listed across the rows of the matrix), if a CAPMF indicator (listed across the columns of the matrix) is selected as relevant by the plug-in LASSO estimation (dark blue), the iceberg LASSO (light blue), or by none of them (grey). In the case of transport and insurance and pension services, no CAPMF indicator is selected by the plug-in LASSO, which implies that no iceberg LASSO estimation is conducted.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

Alternative CAPMF aggregation

While in Section 4.1 we focus on an aggregation of the CAPMF indicators that measures stringency by policy instrument type, estimations were also performed using the original level 2 CAPMF aggregation, which focuses on the area of application of the policies instead. This aggregation results in nine indicators of policy stringency, that further disaggregate the three categories from level 1 aggregation: sectoral policies (electricity, industry, buildings and transport), cross-sectoral (GHG emissions targets, fossil fuel production policies, climate governance) and international (international climate cooperation and emissions data and reporting).⁵¹ In the cases of cross-sectoral and international policies, the aggregation

⁵¹ The original CAPMF level 2 aggregation consists of 15 indicators, from which we exclude research and development expenditure and international public finance due to the high number of missing values on the data. Within the remaining 13, sectoral policies are originally split on market based and non-market based indicators. We aggregate these into a single indicator per sector (electricity, industry, buildings, transport) resulting in 9 indicators.

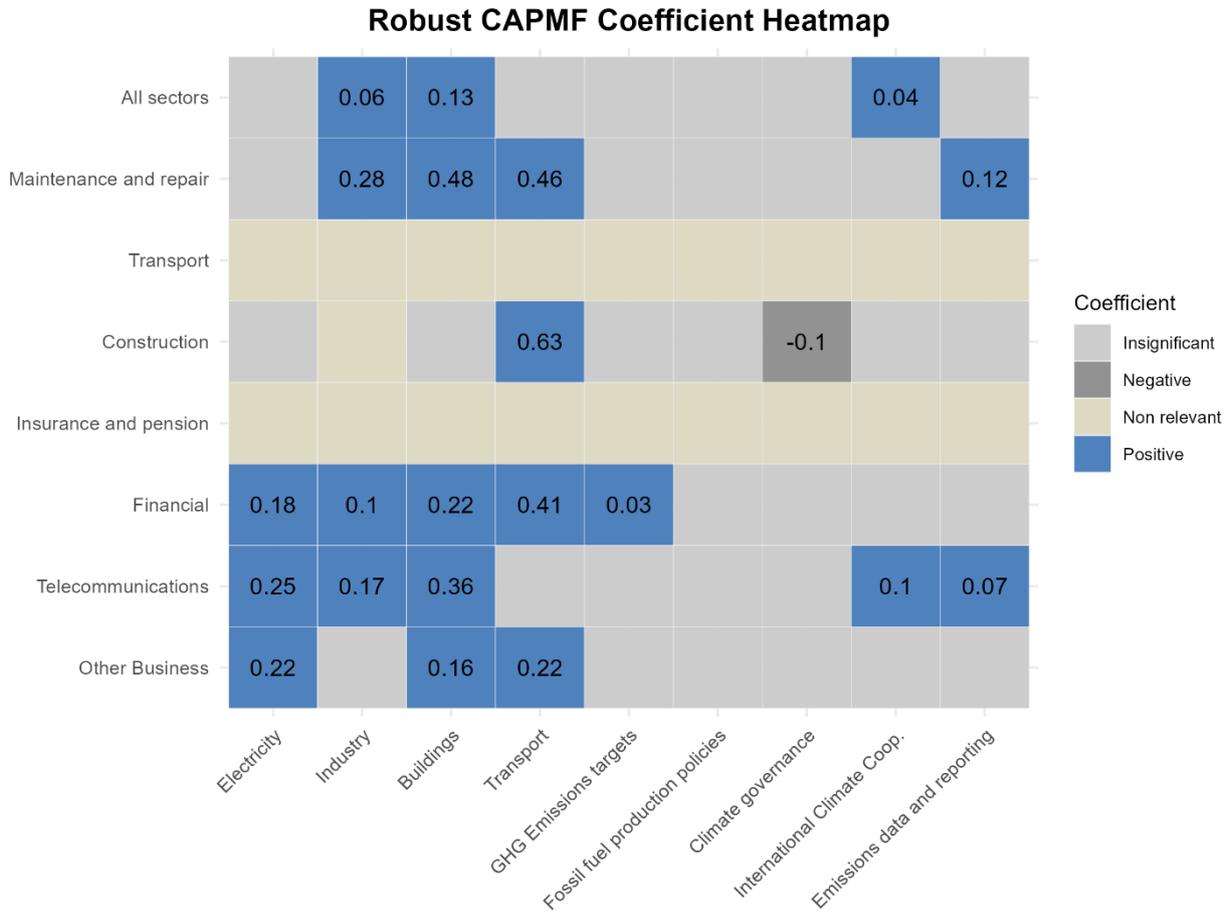
is quite similar to the one used for “policy types”. However, in almost all indicators there are at least slight differences⁵².

Results using this alternative aggregation are shown in Figure A D.3. When comparing these results to those in Figure 9, a similar proportion of robust coefficients indicating a positive differential effect of environmental policy on services imports with respect to internal trade can be observed. This is a logical result, since this is only a different aggregation of the same base data, and therefore it is to be expected that for each services sector a similar proportion of positive effects would appear. As an example, here we also see no LASSO selected coefficients in the transport and insurance and pension sectors, and we see over half of the coefficients being positive in sectors such as maintenance and repair or telecommunications.

Moreover, even when looking at the results by CAPMF indicator, for those in which the difference between an indicator from Figure 9 and an indicator from Figure A D.3 is none or only marginal, the pattern is almost exactly equal the magnitude of the coefficients is similar as well. The additional contribution of this exercise emerges when looking at those CAPMF areas that do not have a direct link with an indicator from the “policy areas “indicator. Policy stringency on the buildings sector seems to show a positive differential impact across the most services sectors, with five positive coefficients on the figure. Policy stringency on transport and industry seem to also have a positive impact across multiple sectors (four coefficients each). Transport also seems to show the largest differential impacts, with a coefficient of 0.63 in construction, and its lowest coefficient (other business services) being of 0.22. Electricity policies seem to only exert a positive impact on three services sectors. On the other hand, fossil fuel production policies seem to have no significant differential impact on services imports and internal trade.

⁵² The original level 2 aggregation groups policies present in the “taxes and fees”, “trading systems”, “subsidies”, “performance standards”, “tech. standards”, “information instruments” and “other NMBIs” policy instrument types by the area the policies target: electricity, industry, buildings or transport sector. The category of fossil fuel production policies captures certain, non-sector-specific policies present in these same policy type categories. GHG targets includes the same policies as the “targets” category in policy types, and “climate governance” also covers the same policies as the equally named variable in the original aggregation. International Climate Coop. covers the same variables as “international coordination” in the policy types, but it also includes some aviation and maritime trading systems that are included in the “trading systems” category in the policy type aggregation. The emissions data and reporting include the same variables as “climate data” but with some additional report variables that were not present in the original aggregation.

Figure A D.3. Summary of the robust assessment of the differential effects of environmental policy stringency on services imports-per sector aggregation

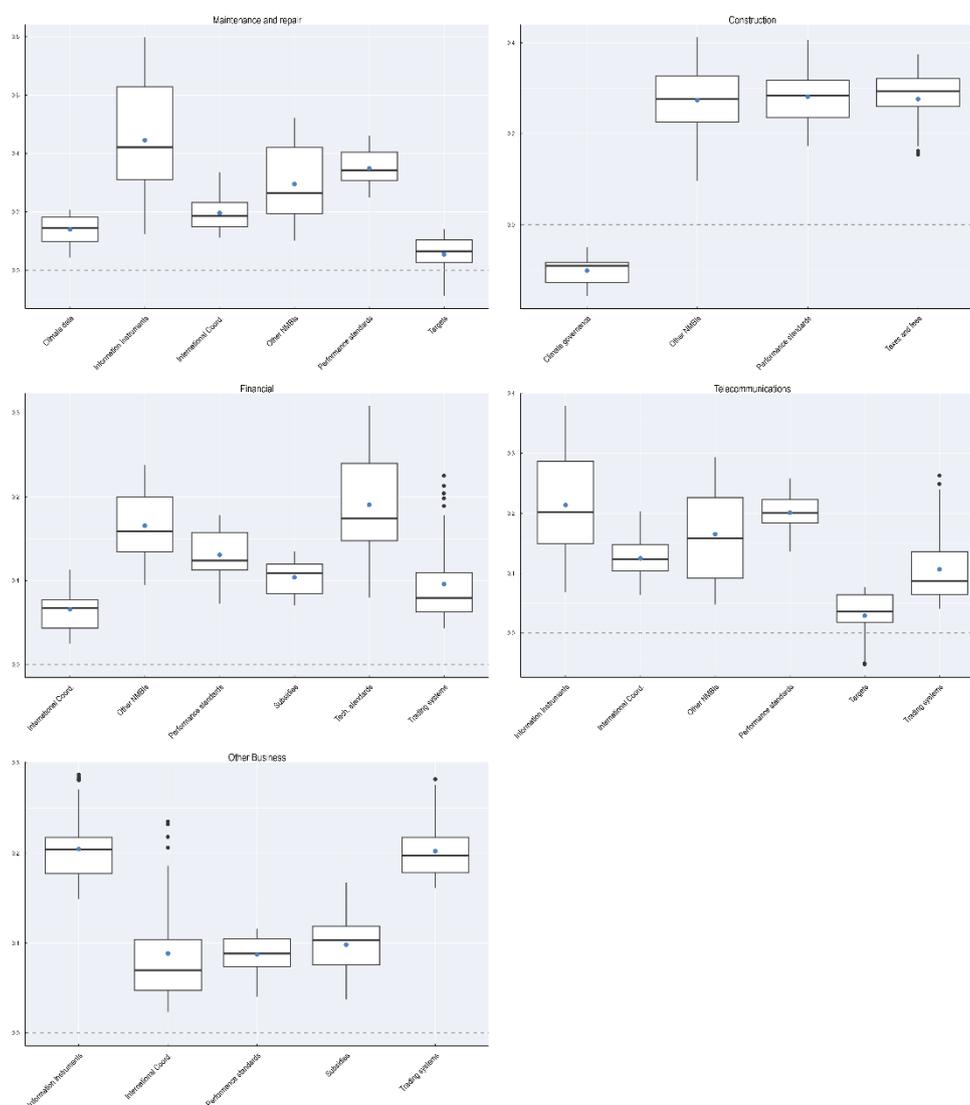


Note: The matrix plotted in the figure characterises each combination of a sectoral category of services imports (row dimension of the matrix) and a dimension of environmental policy (column dimension) with a robust assessment of the estimated differential effect of the latter on the former. This robust assessment is performed by analysing a large but tractable number of estimated differential effects. If less than 90% of these coefficients are significant at the 95% confidence level the cell is labelled as *insignificant*. Colour-codes corresponding to positive and negative labels are assigned when all coefficients are either *positive* or *negative*. If the significance requirement is met, and at least two significant coefficients have a different sign, the cell is labelled as *inconclusive*. When the effect is considered not insignificant, the cell reports the mean estimated effect. In those cases where a CAPMF indicator is not selected as relevant for a services trade variable by the two-step variable selection algorithm, the respective cell is labelled *non relevant*.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

Other figures and tables

Figure A D.4. Distribution of estimated differential effect of CAPMF indicators for services imports by sectoral category



Note: For each CAPMF indicator listed horizontally, the figure shows the box plot of the distribution of all estimated differential effects of the CAPMF indicator on total services imports. These estimates correspond to the estimated coefficient of the interaction term between the international border dummy and the CAPMF indicator in the following gravity specifications: one where the interaction term of interest is included in isolation; all regressions where the interaction term is included in all possible combinations with another interaction term from the list of those selected by either plug-in or iceberg lasso as relevant predictors of services trade; and all regressions where the interaction term is included in all possible combinations with two other interaction terms from the list. Only those CAPMF variables with more than 90% of coefficients significant at the 95% confidence level are included. The plot also includes the mean value of all significant coefficients, represented in blue.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN and ITPD-E.

Table A D.6. Summary statistics for the estimation sample used in the regressions tackling the absolute effect of environmental policy on services imports and domestic sourcing

Variable	Mean	Median	Standard Dev.	Min	Max
Internal trade (rescaled)	0.0636	0.0130	0.1514	0.0000	1.0000
Total imports (rescaled)	0.1102	0.0530	0.1530	0.0000	1.0000
CAPMF average	2.7999	2.4905	1.4055	0.3885	6.9581
GDP	1251977007.8809	378305511.4240	2886551921.1300	12823849.9840	22996100000.0000
GDP per capita	36.8731	35.9010	23.4250	3.3930	135.6830
Inward FDI flow	22558.7465	9347.8296	50432.2593	-101147.6719	467625.0000
Proportion of manufacturing value added of GDP	14.3352	13.5705	5.0892	4.5544	34.6510

Note: This table reports the summary statistics for the variables used in the regressions tackling the absolute effect of environmental policy on services imports and domestic sourcing. The estimation sample consists of 646 observations, covering 38 countries for which CAPMF indicators of environmental policy are observed, for the period 2005-2021. Imports and production are expressed in current USD. CAPMF Country average consists of the average of the four country-level CAPMF stringency indexes with the highest aggregation level. The variables averaged are expressed on a 1 to 10 scale, where 0 (10) indicates minimum (maximum) environmental policy stringency. Both internal trade and imports per country were scaled between 0 and 1 for comparability of results.

Source: CAPMF, STAN, BaTIS and CEPII

Table A D.7. Absolute effect of CAPMF on trade: regression results

VARIABLES	All imports	Internal trade
	(1)	(2)
CAPMF average	0.0342*** (0.00392)	0.000209 (0.000348)
GDP	5.87e-11*** (0)	0*** (0)
GDP per capita	0.00110*** (0.000114)	2.21e-05** (1.04e-05)
Inward FDI flow	7.60e-07*** (8.14e-08)	-2.35e-08*** (7.28e-09)
Manufacturing value added overGDP	0.00229*** (0.000475)	-0.000216*** (3.99e-05)
Constant	-0.135*** (0.0117)	-0.000135 (0.00101)
Observations	623	623
R-squared	0.749	0.994
Year FEs	Yes	Yes
Country FEs	No	No

Note: Regression results for all imports and internal trade on average policy stringency (the average of the three level 1 CAPMF indicators). Both regressions include only year FEs, to exploit across country variation. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' elaboration based on BaTIS, CAPMF, STAN, CEPII, Our world in data and UNCTAD.

Annex E. Supporting material for Section 4.2: Does environmental policy affect the linkages between trade in services and environmental performance?

Empirical strategy for Section 4.2.1

To produce econometrically sound estimations of the linkages between measures of environmental stringency (as main regressors of interest) and services trade and indicators of environmental sustainability (as outcome variables)⁵³ country-level panel regressions with fixed effects are set up. Similarly to estimations in Annex B, the equations are augmented with control variables which control for scale, composition, and technique effect. The empirical investigation of how services trade (or services trade policy), interacted with environmental policy stringency (CAPMF) and environmental sustainability varies at the country-time level is examined through the following equation:

$$y_{it} = \beta_0 + \beta_1 Tot_{services}_{i,t-1} + \beta_2 CAPMF_{i,t-1} + \beta_3 Tot_{services}_{i,t-1} * CAPMF_{i,t-1} + \beta_4 \log(Trade)_{i,t-1} + \beta_5 \log(GDP)_{i,t-1} + \beta_6 FDI_{i,t-1} + \beta_7 Ind_{i,t-1} + \varepsilon_{it} \quad (6)$$

y_{it} is in turn equal to environmental performance indicators explained in Table E.1. Emissions are expressed as emissions intensities (in logs). The coefficient of interest β_3 captures the effects of environmental policy stringency on environmental performance, given a specific level of services imports.

As in other similar specifications in the report, the control variables are in turn: total services and CAPMF, that control for any average effect of both variables separately; $\log(Trade)_{it}$ consists in the sum of exports and imports of country i at time t , representing a trade openness measure. GDP controls for the scale effect. The manufacturing share over GDP, Ind_{it} , controls for the composition effect, i.e. the effect that the structure of the economy (i.e. oriented towards manufacturing or services) can have on the environment.⁵⁴ FDI_{it-1} is the foreign direct investment inflow in a country and captures the effect of trade on the environment driven by the transfer of technologies across countries. All independent variables are lagged, to allow for a minimum time gap between the realisation of services trade flows or policies and environmental performance. Standard errors use the robust estimator for variance in all regressions.

⁵³ Similar settings can also be applied to estimate the relationship between services trade policy at the country-year level and indicators of environmental sustainability.

⁵⁴ For example, one should expect that a change from agriculture to industry leads to an increase in the level of energy consumption, and therefore an increase of the level of pollution. However, to the extent that an economy moves away from industry to the service sector, one should expect the level of emissions to decrease and decouple from economic activity.

Empirical strategy for Section 4.2.2

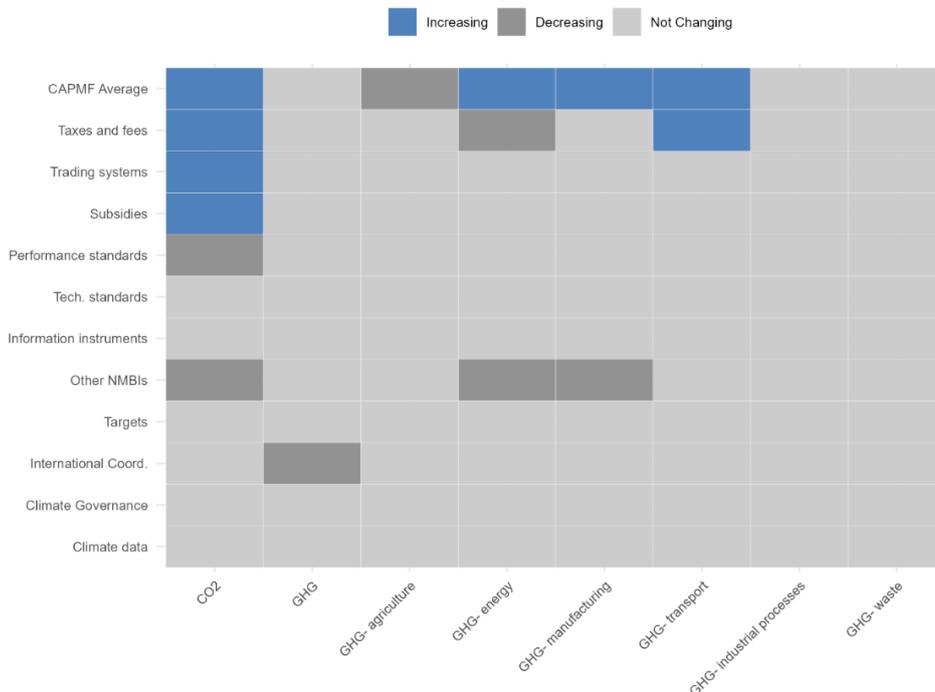
To investigate the effect of environmental policy through CAPMF, in the relation between services trade policy and environmental performance in downstream manufacturing sectors, equation 7 is augmented by an interaction term between CAPMF and services restrictiveness index upstream, and a control variable for environmental policy, namely CAPMF alone. The baseline estimation regression is then:

$$y_{ijt} = \beta CSTR I_{ijt} + \rho CAPMF_{it} + \sigma CSTR I_{ijt} * CAPMF_{it} + \gamma' X_{ijt} + \delta_{it} + \theta_{jt} + \lambda_{ij} + \varepsilon_{ijt} \quad (7)$$

where y is the dependent variable (CO2 intensity in production, in logs); $CAPMF_{it}$ is an average indicator for environmental policy, X is a vector of control variables that include input tariffs, output tariffs, export share, import share and labor productivity (value added per employee); δ_{it} are country-time fixed effects; θ_{jt} are sector-time fixed effects; and λ_{ij} are country-sector fixed effects. The coefficient β is expected to be positive: because of the technique effect, higher services trade restrictiveness should deteriorate environmental performance, and therefore increases CO2 intensity in production, of downstream manufacturing industries. The coefficient σ captures the effect of trade restrictiveness on emissions intensity, for a given level of environmental policy. It is expected to be positive, as higher levels of services trade restrictiveness would lead to a higher CO2 emission intensity for downstream manufacturing sectors.

Figures and tables

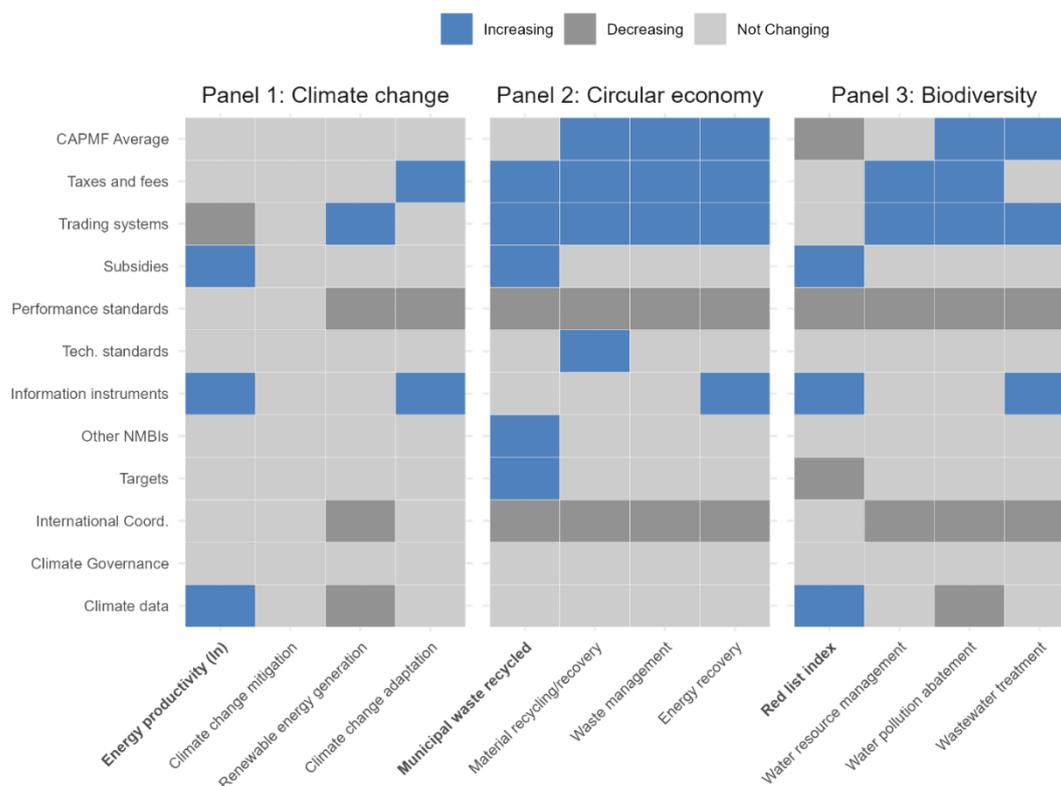
Figure A E.1. Environmental policies shaping the linkages between services imports and emission intensity indicators



Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with services trade on emission intensity indicators. The estimations include year fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval.

Source: CAPMF, BaTIS, Air and GHG emissions database. Increased sustainability, in this case, refers to a decrease in emission intensity, so it reflects a negative coefficient for the corresponding indicator.

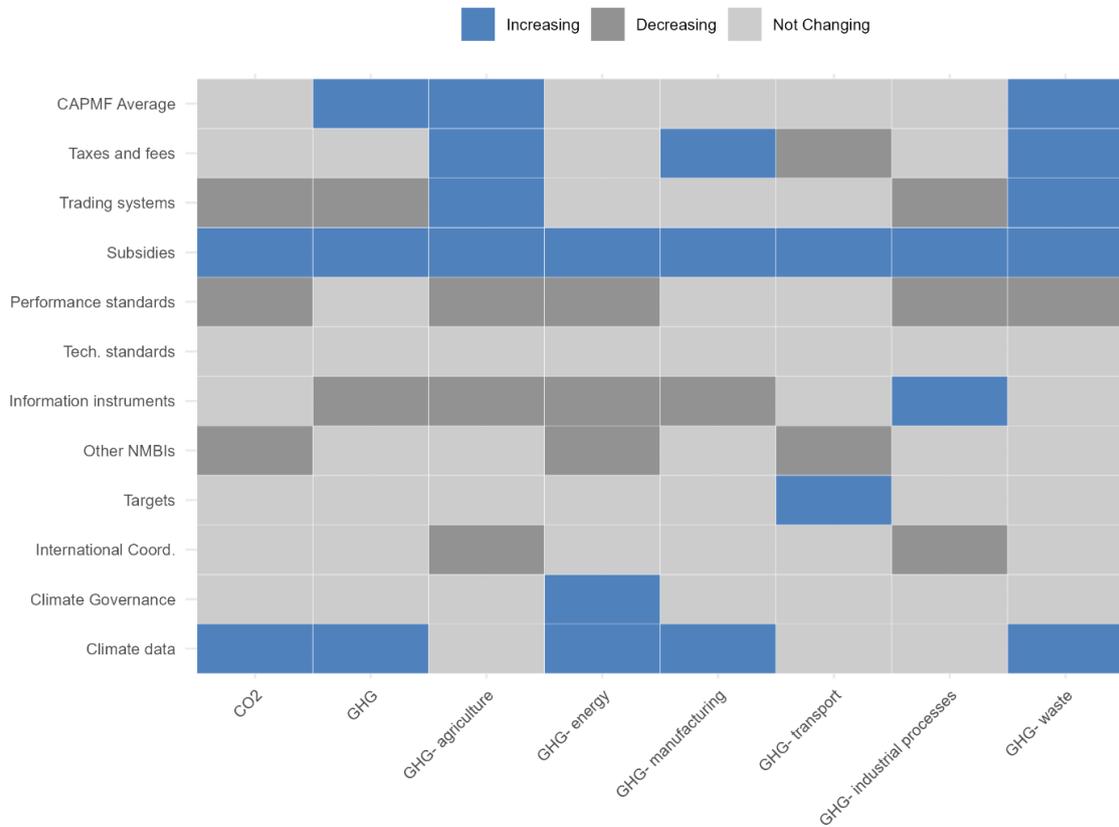
Figure A E.2. Environmental policies shaping the linkages between services restrictiveness and environmental performance indicators



Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with the STRI average index on environmental performance indicators. Those indicators in bold represent environmental outcomes, while the rest are innovation indicators. The estimations include year fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval.

Source: CAPMF, OECD STRI Database, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A E.3. Environmental policies shaping the linkages between services restrictiveness and emission intensity indicators

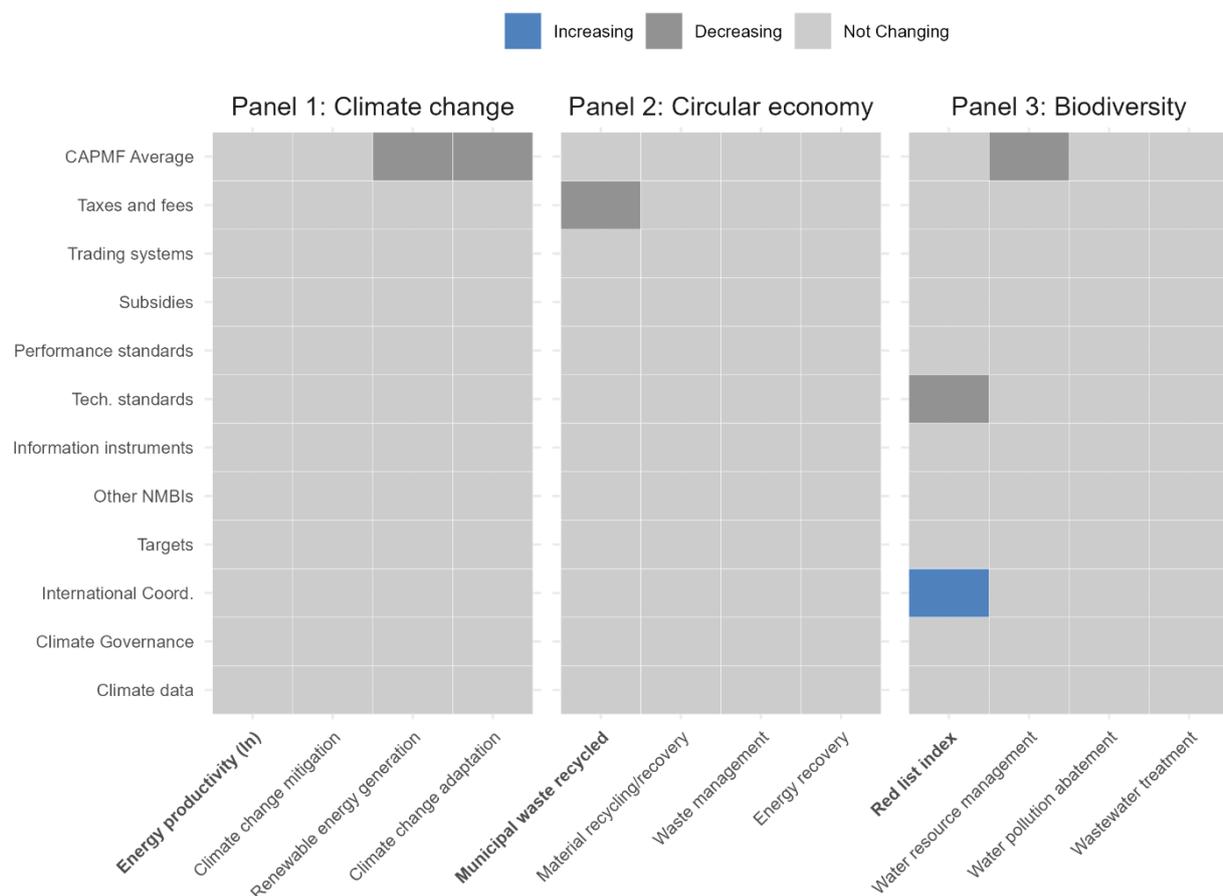


Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with the STRI average index on emission intensity indicators. The estimations include year fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval. Increased sustainability, in this case, refers to a decrease in emission intensity, so it reflects a negative coefficient for the corresponding indicator.

Source: CAPMF, OECD STRI Database, Air and GHG emissions database.

Figure A E.4. Environmental policies shaping the linkages between services imports and environmental performance indicators

Estimations with country fixed effects and economic development controls

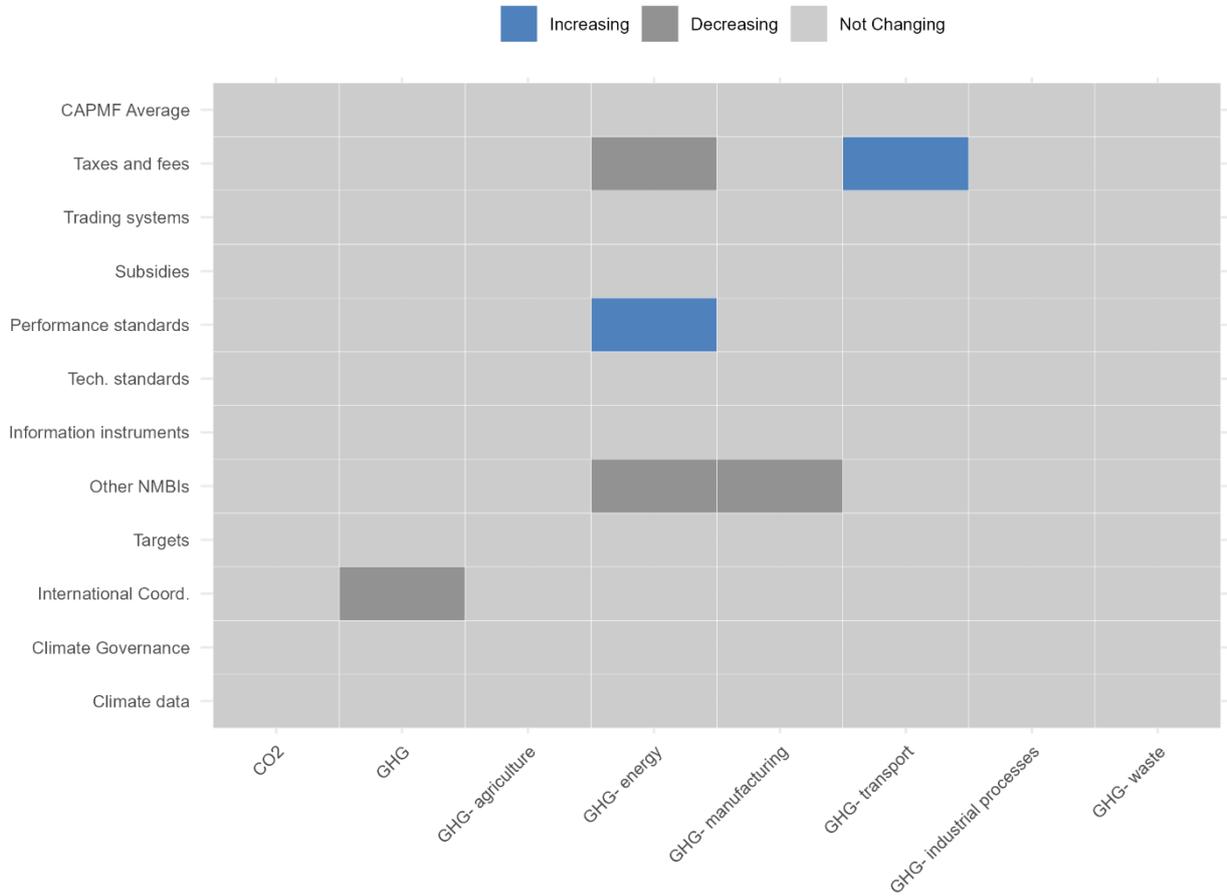


Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with services trade on environmental performance indicators. Those indicators in bold represent environmental outcomes, while the rest are innovation indicators. The estimations include year and country fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval.

Source: CAPMF, BaTIS, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A E.5. Environmental policies shaping the linkages between services imports and emission intensity indicators

Estimations with country fixed effects and economic development controls

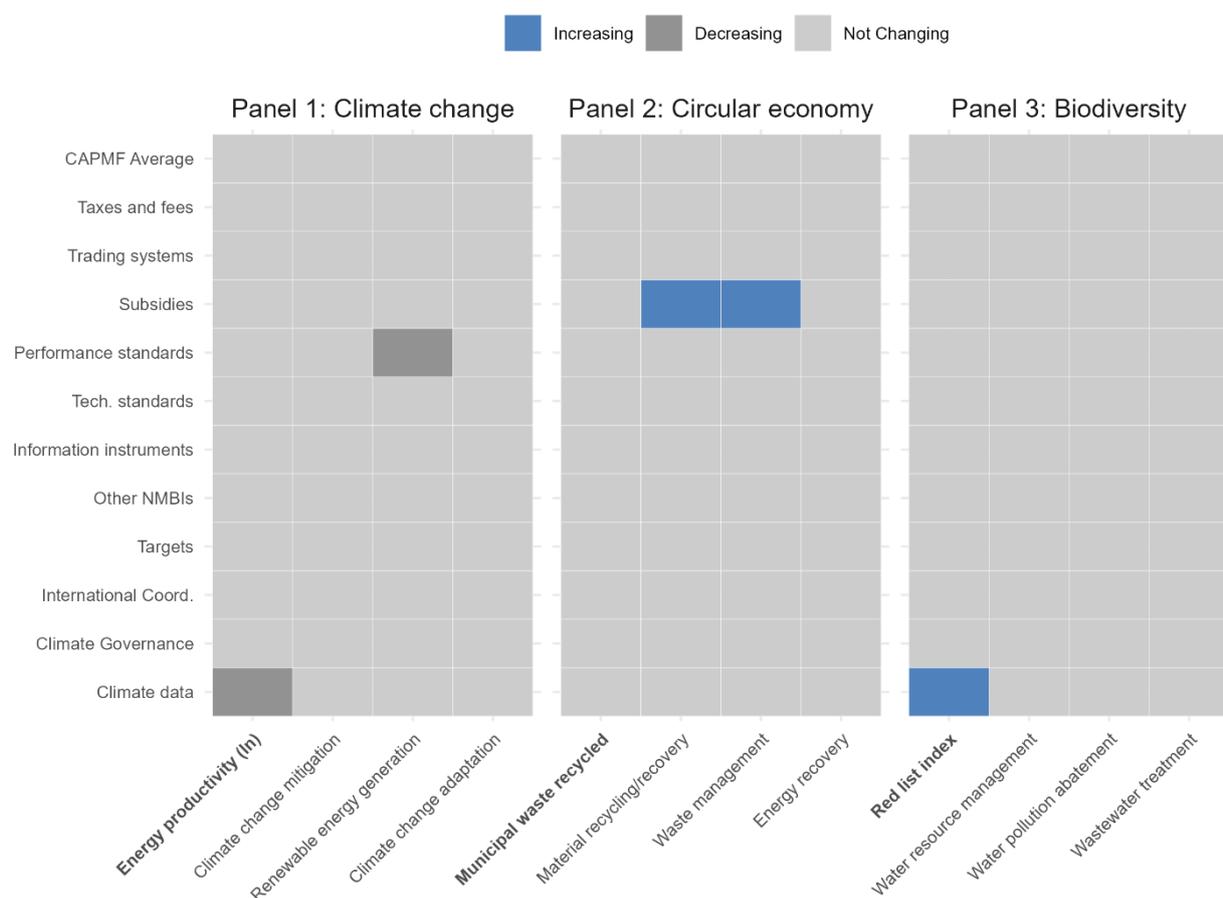


Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with services trade on emission intensity indicators. The estimations include year and country fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval. Increased sustainability, in this case, refers to a decrease in emission intensity, so it reflects a negative coefficient for the corresponding indicator.

Source: CAPMF, BaTIS, Air and GHG emissions database.

Figure A E.6. Environmental policies shaping the linkages between services restrictiveness and environmental performance indicators

Estimations with country fixed effects and economic development controls

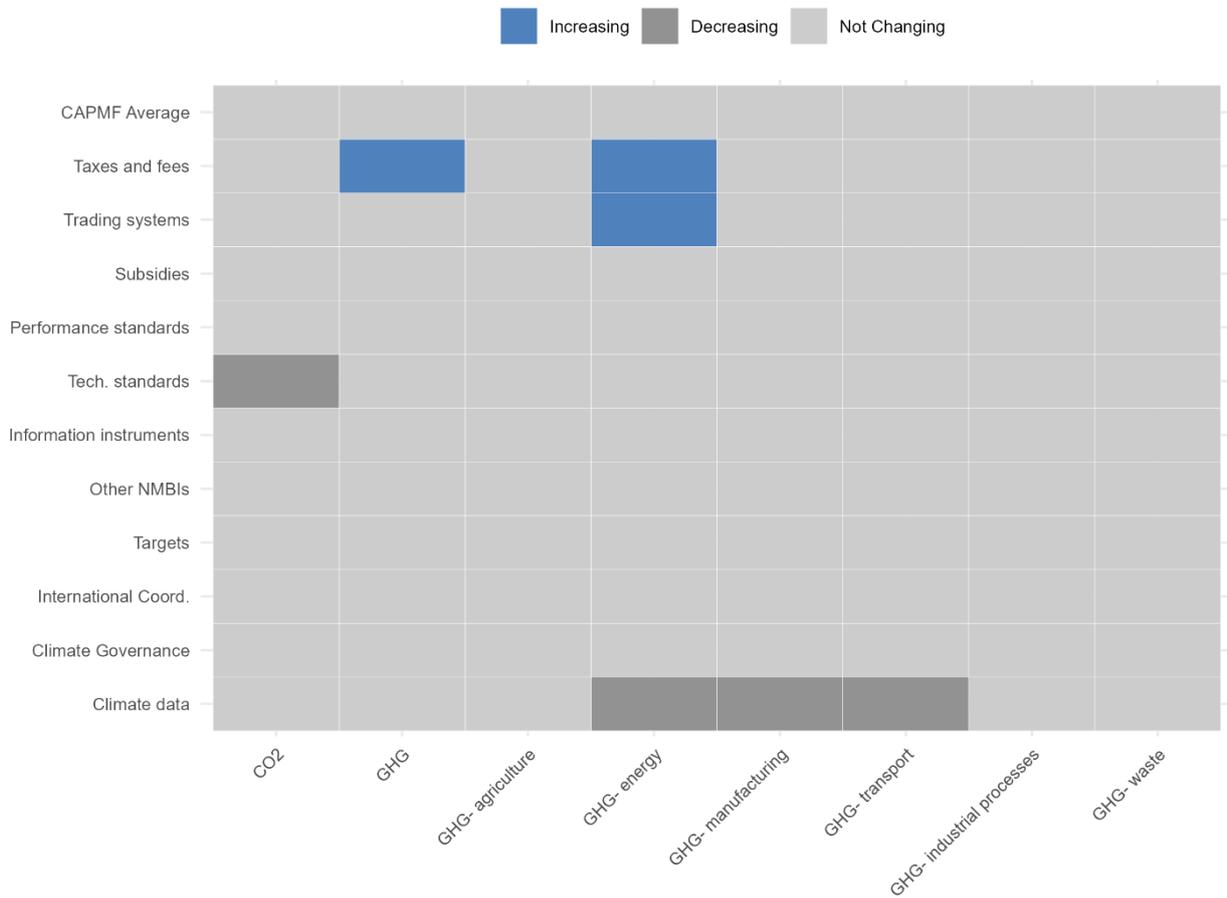


Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with the STRI average index on environmental performance indicators. Those indicators in bold represent environmental outcomes, while the rest are innovation indicators. The estimations include year and country fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval.

Source: CAPMF, OECD STRI Database, Green growth indicators, Patents technology dataset, Our World in Data.

Figure A E.7. Environmental policies shaping the linkages between services restrictiveness and emission intensity indicators

Estimations with country fixed effects and economic development controls



Note: This figure shows the estimation coefficients of the relation between the interaction of different CAPMF indicators with the STRI average index on emission intensity indicators. The estimations include year and country fixed effects and clustered standard errors. The blue cells are related to increased sustainability at 95% of confidence interval. Increased sustainability, in this case, refers to a decrease in emission intensity, so it reflects a negative coefficient for the corresponding indicator.

Source: CAPMF, OECD STRI Database, Air and GHG emissions database.