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# THE POTENTIAL IMPACT OF ENVIRONMENTAL GOODS TRADE LIBERALIZATION ON TRADE AND EMISSIONS

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# The Potential Impact of Environmental Goods Trade Liberalization on Trade and Emissions*

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**Abstract**

We combine econometric estimation with quantitative modelling to generate projections on the trade, GDP, and emissions effects of a potential trade liberalization agreement in energy related environmental goods (EREGs) and environmentally preferable products (EPPs). Trade liberalization can contribute to reduced emissions in two ways in our projections: (i) a reduction of import prices of goods promoting energy efficiency; (ii) a reduction in the costs of intermediate and capital goods used in the production of electricity from renewable sources. We evaluate four scenarios combining reductions in tariffs and non-tariff measures (NTMs) of EREGs and EPPs. Using simulations with the WTO Global Trade Model findings show (i) an increase in exports of EREGs and EPPs both at the global level and in most regions; (ii) a modest increase in GDP in all regions because of falling tariffs, NTMs, and increased energy efficiency; (iii) a modest reduction in global emissions of about 0.6%. The dominant channel is energy efficiency whereas the costs of EREGs as intermediates in renewable energy production play a minor role, with or without end use control.

**Keywords:** Environmental Goods (EGs), Trade Liberalization, Emissions, Energy efficiency.

**JEL Classification:** F14, F13, F17, F18, Q56

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# 1 Introduction

The shift from fossil-fuels towards low-carbon and renewable energy sources is crucial to tackle climate change. The use of environmental goods and services (EGS) can be an important tool in facilitating the reduction in greenhouse gas (GHG) emissions and reducing their trade costs can contribute to improved access to EGS. However, despite an extensive literature on trade in EGS, its impact on specific environmental issues has not been the focus of much research and is still not well understood. There are two main reasons for this.

The first reason relates to data. There is a lack of internationally comparable data on trade in environmental goods (EG), with even fewer data available on trade in environmental services (ES). One problem is that while the concept of EGS is rather intuitive, defining the scope of EGS has proven to be a complex exercise, in particular in the context of trade negotiations. EGS have been defined relatively broadly as goods and services used to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems (OECD and Eurostat, 1999). They include cleaner technologies, products and services that reduce environmental risks and minimize pollution and resource use. This means that only a subset of EGS can be related to tackling carbon emissions through the use of renewable energy or an increase in energy efficiency, to take just one example.

Over the years, various classifications and lists of EGS have been developed for different purposes, including statistical analysis and trade negotiations. In this context, the environmental objective and the main end-use purpose of EGS are two of the main criteria that have been considered to delimit the scope of EGS. OECD pioneered this classification work in the 1990s, followed by joint work of the OECD and Eurostat, discussions between APEC Members, and talks in the WTO. In 1995, UNCTAD proposed a list of environmentally preferable products (EPP), defined as products which, over their entire life cycle, including production, processing, consumption and disposal, cause significantly less environmental harm than alternatives.(UNCTAD, 1995).

Another difficulty when generating internationally comparable EG trade statistics arises because trade-flow data on goods are collected and organized according to Harmonized System (HS) codes, but few of the HS's six-digit subheadings (HS6) specifically cover goods that are mainly used for environmental purposes. A large share of EG is classified under generic subheadings, and is not separately identified, making it difficult to measure the size and pattern of world trade in the relevant goods. Because of this difficulty in separating EG from other goods, and because some of these products can both benefit and harm the environment depending on their use (i.e., dual use), most trade data actually result in an overestimation of trade in EG.

The second reason explaining the limited amount of research on the environmental effects of trade in EGS is that the mechanisms through which trade in EGS affects carbon emissions and other environmental outcomes are complex to capture and to quantify. In particular, the large number of channels through which trade in EG can affect economic and environmental outcomes makes the overall effect difficult to model.

Notwithstanding these difficulties, different empirical studies have attempted to measure the impact of trade liberalisation in EGS on GHG emissions and other environmental outcome measures. Using a simulation exercise, Hu et al. (2020) find that lowering the cost of intermediate inputs in renewable energy induces a transition from non-renewable to renewable energy production and thus a reduction of emissions. However, such a reduction in production costs also generates an increase in economic activity, leading to more emissions. Furthermore, lower costs of intermediate inputs used in the generation of renewable sources of energy also reduce the costs of intermediate inputs used in the production of fossil fuels. However, Hu et al. (2020) assume that so-called end use control can be applied when liberalizing trade of EGS, i.e. trade costs of intermediates can be reduced when bought by renewable sectors but not when bought by non-renewable sectors. Employing end use control, CO2 emissions are projected to fall by 0.12% with EG liberalization.

Several empirical studies have focused on the effect of trade in EG on different outcome variables, showing that the effect on emissions is sometimes ambiguous due to opposite effects on different types of emissions and the dual use of environmental goods, which do not only have an environmental purpose (Zugravu-Soilita (2018), Zugravu-

Soilita (2019)). Other studies compared the impact of opening trade in EG and in non-environmental goods on environmental quality measured by different types of emissions and found that opening trade in EG improves environmental quality significantly more than opening trade in non-environmental goods (De Alwis (2014)). Tamini and Sorgho (2018) using a gravity approach, estimated a modest emission reducing effect of EG trade liberalization, pointing out the importance of addressing non-tariff barriers. Wang et al. (2021) find that trade liberalization in solar cells and modules could reduce global CO2 emissions between 2017 and 2060 by 0.3%-0.9%.

This paper aims to complement the existing analysis on the impact of trade liberalisation of EGS on GHG emissions, by combining econometric estimation with quantitative modelling to generate projections on the trade, GDP, and emission effects. We employ the electricity version of the WTO Global Trade Model (GTM), a recursive dynamic computable general equilibrium (CGE) model with multiple countries, sectors, and production factors, emissions related to production, and a detailed energy module with energy produced from fossil fuels (oil, gas, and coal) and electricity which is in turn produced with fossil fuels or renewable sources of energy (solar and wind).[1]

In the counterfactual experiments, we focus on a restricted list of environmental goods (EG) only[2] consisting of Energy Related Environmental Goods (hereafter EREG). EREG comprise goods that help in the production of clean and efficient energy such as clean and renewable energy goods (CRE), resource efficiency (RE) and energy efficiency (EE) goods. Clean and renewable energy (CRE) goods include all products required for the generation of electricity by methods that are environmentally preferable to conventional alternatives, such as "Wind-powered electric generating sets" that are important inputs to wind power generation. Energy efficiency (EE) goods help managing and restraining the growth in energy consumption. For example, using LED light[3] instead of filament lamps would reduce energy consumption as the former is more energy efficient. Resource Efficiency (RE) goods are, in nature, close to EE and CRE as they operate

[1]Further details of the model are in Bekkers and Cariola (2022).

[2]Despite the inclusion of environmental services in specific categories of EGS, due to data restrictions in the modelling study, we could not include services with an energy related purpose.

[3]Corresponding to HS6 8541.40 code on APEC's list.

through the same channel and aim at reducing energy consumption.[4]

For completeness, we also incorporate environmentally preferable products (EPP) in the liberalization experiments. Altogether, we explore four scenarios combining reductions in tariffs and non-tariff measures (NTMs) of EREG and EPP. Trade liberalisation of EREG contributes to emission reductions along two channels in our study: (i) an increase in energy efficiency through the reduction in import prices of products instrumental in raising energy efficiency and; (ii) a reduction in the costs of intermediate and capital goods used in the production of electricity from renewable sources. It is important to note that at the same time, trade liberalisation also raises emissions through a scale effect, limiting the beneficial impact.

The first channel is modelled by expressing energy efficiency as a function of the price of intermediate inputs of EREG with the elasticity disciplined by econometric estimates. More specifically, regional CO2 emissions are regressed on imports of EREG showing that such imports reduce emissions in most regions. These estimates are employed to discipline the relationship in the model between energy efficiency and the price of intermediate inputs of EREG.

The second channel emerges endogenously in the model: trade liberalization of EREG generates a reduction in the price of intermediate inputs and capital goods employed in renewable energy which in turn leads to a substitution of energy generated with fossil fuel by energy generated with renewables sources. This channel can be magnified by imposing so-called end use control as in Hu et al. (2020), with trade costs only falling if intermediates are bought by renewable energy sectors.

Trade liberalisation of EPP can play a role in emissions through a cost reduction of EPP, leading to an increased use of environmentally preferable products compared to other products. However, we do not model the impact of EPP on emissions, since emission data at the detailed product level are not available and so it is not feasible to model the potential substitution in consumption and production towards EPP.

Simulating the trade liberalisation scenarios described with the GTM generates three

[4]Resource efficiency denotes the efficiency with which resources are used in an economy or in a production process.

main insights: (i) an increase in exports of EREG and EPP both at the global level and in most regions; (ii) a modest increase in GDP in all regions because of falling tariffs, NTMs, and increased energy efficiency; (iii) a modest reduction in global emissions of about 0.6%. The dominant channel is energy efficiency whereas the decreased costs of EREG as intermediates in renewable energy production play a minor role, with or without end use control.

This paper makes three main contributions to the literature. First, we employ a combination of econometric estimation with a rigorous general equilibrium model to evaluate the impact of environmental goods trade on CO2 emissions. Second, we explore a new channel through which trade in environmental goods can reduce emissions, the reduction in import prices of products instrumental in raising energy efficiency. As such the emission reducing effect of environmental goods trade is not dependent on end use control in the design of tariff liberalisation. Third, we show that the contribution of the shift from fossil fuels to renewables in electricity because of lower prices of EGS to emission reductions is minimal, also under end use control.

The rest of the paper is organized as follows. Section 2 starts with a background of discussions on environmental goods and the different channels through which more trade in the considered environmental goods could affect the environment. Section 3 describes the methodology used in the study, followed by a discussion of the results in Section 4. Section 5 concludes.

# 2 An Overview of Environmental Goods (EG) and the Relation with Emissions

In this section we first provide a historical overview of discussions on lists of environmental goods. Then, we cover different categories EGs describing which goods we will focus on in this study. Finally, the channels through which trade in environmental goods is expected to impact CO2 emissions.

## 2.1 A History of Talks on EGs

In the early 1990s, the OECD created a list to illustrate the scope of the environment industry, which was a result of joint OECD and Eurostat work on a manual for national statisticians to assist them in measuring their national environmental industries (Eurostat (1999)). In November 1995, APEC leaders identified industries for which the progressive reduction of tariffs could have a positive impact on trade and economic growth in the Asia-Pacific region, resulting in the APEC list of environmental goods that limited itself to considering only those specific goods that could be readily distinguished by customs agents and treated differently for tariff purposes.[5]

In November 2001, the Doha Declaration was signed, agreeing to negotiations, without prejudging their outcome, on the reduction or elimination of tariff and non-tariff barriers to environmental goods and services. Members adopted a list-based approach under which each member would propose a set of potential environmental goods (defined at the HS6 level on which trade barriers should be reduced or eliminated. The OECD and APEC lists served as basis for these lists generating three lists: the WTO combined list (411 HS6 lines), the core list (26 HS lines), and the "Friends of environmental goods" list (154 HS lines). The WTO combined list (411 HS6 lines) aggregates all submissions made under the Doha negotiations until 2011.[6] Thirteen members participated in the process.[7] The Core list consists of 26 products, derived from the WTO combined list, identified as "clear environmental goods". It had the objective of serving as a basis for negotiations under the Doha Development Agenda (DDA) in 2010 (Balineau and De Melo, 2013). The Friends List consists of 153 HS6 lines and was published in 2009 by a group of WTO members called the "Friends of environmental goods".[8]

[5]As stated in Steenblik (2005) both the OECD and APEC products lists were interlinked and informed each other, though the purpose was different. The OECD list contained broader categories of goods because there were no specific policy consequences of adding products to the list, whereas since the APEC list's aim was to obtain more favourable tariff treatment for environmental goods, APEC member economies limited themselves to considering only those specific goods that could be readily distinguished by customs agents and treated differently for tariff purposes.

[6]JOB/TE/3/Rev. 1 (2011), see: `https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=Q:/TN/TE/20.pdf&Open=True`

[7]Saudi Arabia, Kingdom of (262 HS6 lines), Japan (57), Philippines (17), Qatar (20), Singapore (72), and the Friends' list (164), a merger of lists by Canada, the European Union, Japan, Korea, Republic of, New Zealand, Switzerland, Chinese Taipei, the United States of America, and Norway (De Melo and Solleder, 2020).

[8]Countries that are included are Canada, the European Union, Japan, Korea, Republic of, New Zealand,

In 2012, APEC members committed to reducing applied tariffs on a list of 54 environmental goods to below 5% by the end of 2015. In July 2014, a group of 46 WTO members launched a negotiation to establish an Environmental Goods Agreement (EGA), with the aim of eliminating tariffs on a number of important environmental goods.[9] The APEC list served as a starting point for the EGA negotiations. Table 1 provides a concise overview of the main lists discussed in this paragraph, with partially overlapping HS6 lines.[10]

Table 1: Lists of Environmental goods for trade negotiation

| List | Number of HS6 codes | Assembling parties |
|---|---|---|
| **Early lists** | | |
| OECD list | 164 | OECD |
| APEC list | 109 | APEC |
| **Trade Negotiation lists** | | |
| Friends' list (2009) | 154 | Subset of WTO list containing submissions by Canada, the European Union; Japan; Korea, Republic of New Zealand; Norway; Switzerland; Chinese Taipei; and the United States of America |
| Doha negotiations list (2011) | 411 | 13 WTO members[11] |
| Core list (2011) | 26 | Subset of WTO list selected by Australia; Colombia; Hong Kong, China; Norway; Singapore |
| APEC list (2012) | 54 | APEC members |

Source: Steenblik (2005), JOB(09)132; JOB/TE/3/Rev. 1; TN/TE/20; Leader's declaration, APEC ministerial 2012.

Countries participating in talks about environmental goods consist mostly in developed economies. This is mainly because the goods on the different lists, are mainly goods for which high-income economies have a comparative advantage.[12] As early as 1995, UNCTAD was advocating the use of EPP as an opportunity for developing countries. The work by UNCTAD was later extended by the OECD and a list of EPP, representative of the comparative advantage of developing countries, was established.[13]

Norway, Switzerland, Chinese Taipei, and the United States of America.

[9]Participating countries were Australia; Canada; China; Costa-Rica; European Union; Hong Kong, China; Iceland; Israel; Japan; Korea, Republic of; New-Zealand; Norway; Singapore; Switzerland; Chinese Taipei; Türkiye; and the United States of America.

[10]Although the lists included in Table 1 are the most referred to, the table is not exhaustive.

[12]See De Melo and Solleder (2020) for a discussion.

[13]See Tothova (2005) for the list which partially overlaps with the other lists discussed above.

## 2.2 An overview of environmental goods categories

Environmental goods can be split up into two main groups (Balineau and De Melo, 2013): Goods for Environmental Management (GEM) and Environmentally Preferable Products (EPP). The list of EPP builds on the EPP list of UNCTAD (1995) and suggests a long number of possible qualifying products.[14] As explained in Tothova (2005), it divides the illustrative additions into seven broad categories: environmentally preferable (EP), transportation, energy, pollution control, life-cycle extension, EP alternatives, and waste and scrap. Each category includes several sub-categories, including complements, parts, and infrastructure, where applicable.

GEMs can be further divided in 9 sub-categories, as listed in Table 2. Among the list of GEMs, this study will only concentrate on energy efficiency (EE), resource efficiency (RE), and clean and renewable energy (CRE) categories that we define as Energy Related Environmental Goods (EREG). It is nevertheless important to underline that some EREG serve various environmental purposes, and can thus fall under several sub-categories. For example, *HS6 8541.40* can be considered a CRE, RE and EE, depending on its final use.[15]

Table 2: List of Goods for Environmental Management (GEM) sub-categories

| Abbreviation | Corresponding environmental good category |
|---|---|
| **Energy Related Environmental Goods (EREG)** | |
| CRE | Clean and Renewable Energy |
| EE | Energy Efficiency |
| RE | Resource Efficiency |
| **Other GEM** | |
| APC | Air Pollution Control |
| EMAA | Environmental monitoring, analysis and assessment |
| ERC | Environmental remediation and clean-up |
| NVA | Noise and vibration abatement |
| SHWM | Solid and Hazardous Waste Management |
| WMWT | Wastewater management and water treatment |

Note: EREG consist of a list of climate or energy related goods put together for analytical and research purposes.

Clean and renewable energy (CRE) goods include all products required for the gener-

[14] Examples of EPP are sisal plant, bicycles, etc.

[15] Product line *HS6 8541.40* is defined as ”Photosensitive semiconductor devices, including photo-voltaic cells whether or not assembled in modules or made up into panels; light-emitting diodes (LED)”. These diodes can be part of a solar panel and thus help produce renewable energy (CRE) or be used to build lamps and reduce energy consumption (EE, RE).

ation of electricity by methods that are environmentally preferable to conventional alternatives. Some goods in the CRE category and in other categories in general are however harder to identify at the HS6 level. Indeed, most EG are defined at the 8- or 10-digit tariff lines (even in some cases with ex-outs), making the distinction of EG at the HS6 complex. As a result, any analysis at the HS6 level provides upper-bound estimates. The HS6 code 84.7990, corresponding to "Machines and mechanical appliances having individual functions, not specified or included elsewhere" is also part of EG lists as it contains parts and equipment used in machines considered as EG, but it has a broader definition. As goods in these HS lines are also used in a broad range of other applications, including non-environmentally friendly applications, there is a so called "multiple end-use problem". That is, goods from the same HS6 line can have clean and dirty uses from an environmental perspective. Energy efficiency (EE) goods help managing and restraining the growth in energy consumption. For example, as mentioned above, using LED light (corresponding to HS6 8541.40 code on APEC list) instead of filament lamps would reduce energy consumption as the former is more energy efficient. Resource Efficiency (RE) goods are, in nature, close to EE and CRE as they operate through the same channel and aim at reducing energy consumption. Resource efficiency denotes the efficiency with which resources are used in an economy or in a production process. In addition, RE goods, as many other environmental goods, are often used in conjunction with environmental services[16] and are mostly concerned with the resource consumption in the life cycle of a product.

The three above mentioned types of GEM will be at the centre of our analysis. To ease the reading, hereafter, we will refer to these categories together as EREG.

## 2.3 Channels and expected effects of trade liberalization in environmental goods

There are several channels through which trade liberalization in EREG and EPP may contribute to less emissions.

[16]Discussions on Environmental Services (ES) have been left out of the negotiation agenda.

First, trade liberalization in EREG leads to a reduction in input prices that serve to produce renewable energy. Lowering the cost of clean technology inputs compared to conventional technology inputs is expected to induce a transition from dirtier to cleaner energy sectors, similar to what the literature refers to as a composition effect, reducing emissions (Copeland and Taylor 2003).[17] However, such a reduction in production costs also generates an increase in economic activity (what is commonly known as a scale effect)[18], leading to more emissions (Hu et al. (2020)). For instance, trade liberalization in EREGs may result in an increase of overall economic activity and, thus, in an increase in demand for energy, including coal and oil in some countries (e.g., Russian Federation, Saudi Arabia, Kingdom of). This is also known as a rebound effect. Another worth mentioning issue that affects the overall effect of trade liberalization in EG on emissions is the "multiple end-use problem" (see subsection 2.2). In that situation, trade liberalization in EREG can lead to a reduction of production costs in conventional technologies (Hu et al. 2020), thus limiting the reduction in emissions.

Second, using more EREG leads to changes (improvements) in energy efficiency, which reduces emissions from production through a more efficient use of energy (similar to a technique effect).[19] The energy efficiency can be reflected in production and consumption. An increase in energy efficiency in production implies that the same output can be produced with less energy inputs and an increase in energy efficiency in consumption implies that the same amount of a final good can be consumed with less energy inputs. For instance, heat recovery steam generators/combined heat and power boilers consist in an energy recovery heat exchanger that recovers heat from a hot gas stream. It produces steam that can be used in a process (cogeneration) or used to drive a steam turbine (combined cycle). Combined heat and power boilers contribute to energy efficiency by using the waste heat in power generation activities.

In addition, trade liberalization in EPP induces the use of products that cause signif-

[17]The composition effect measures the changes in environmental degradation due to changes in the range of goods produced, assuming constant scale and technique of production.

[18]Econometric studies find support for both competing effects (e.g., Zugravu 2018, 2019).

[19]The technique effect measures the change in aggregate pollution (or environmental degradation) arising from a switch to more environmentally sustainable production techniques, assuming constant scale and composition effects (Copeland and Taylor 2003).

icantly less *environmental harm* at some stage of their life cycle compared to alternative products serving the same purpose (Tothova, 2005). The use of such goods can bring environmental benefits from production, consumption, and disposal.

To circumvent any issue related to goods that serve an environmental purpose but do not necessarily affect emissions (e.g. an EG used to clean water), our analysis will concentrate on a list of 177 HS6 codes of EREG containing mainly intermediate and capital goods related to clean and renewable technology, energy and resource efficiency. It is a list of energy-related environmental goods that has been put together for analytical and research purposes.

# 3 Model, Data, Calibration, and Scenarios

In this section we describe in turn the employed general equilibrium model, the way in which trade in EREGs is projected to affect emissions, the data employed, and the trade liberalisation scenarios.

## 3.1 The general equilibrium model

To model the potential impact of trade liberalization in EREG on CO2 emissions, the energy and electricity version of the WTO Global Trade Model is used, a recursive dynamic computable general equilibrium (CGE) model, with a detailed energy module. In the model, energy is partially substitutable with capital and there is a nested constant elasticity of substitution (CES) of fossil fuel inputs and electricity which in turn can be produced from fossil fuels and from renewable energy. CO2 emissions are related to the use of fossil fuels by firms and private households in the model.[20] Further details of the model are provided in Bekkers and Cariola (2022).

Starting from the GTAP Data Base, Version 10, with base-year 2014 a baseline projection until 2030 for the global economy is generated by imposing external projections for GDP per capita growth, labor force growth, differences in productivity growth between sectors, and changes in trade costs. We also include shocks to the energy module. Follow-

[20] We focus on CO2 emissions and do not consider other greenhouse gas emissions in this study.

ing Bekkers and Cariola (2022) productivity of renewables is growing based on historical projections of solar and wind productivity and the path of global CO2 emissions is calibrated to emissions projected by the International Energy Agency (IEA) as reported in Böhringer et al. (2021) by shocking energy efficiency in the model.

## 3.2 Data

We employ the Power version of the GTAP Data Base, Version 10, for 2014. This database contains information about CO2 emissions with the CO2 emissions are related to the use of fossil fuels in production. Furthermore, it contains a breakdown of the electricity sector into 12 subsectors, Transport and Distribution, and 11 electricity generating sectors. We aggregate these sectors into 8 electricity sectors, electricity generated from nuclear energy, coal, gas, wind, hydro-energy, oil, other energy, and solar energy. GTAP regions are aggregated into 24 regions as shown in Table A-1 of the Appendix. The regions in the study are displayed in Table 3. There are 27 sectors in total, as shown in Appendix Table A-2.

Table 3: Overview of region names in the model

| Name | Region | Name | Region | Name | Region |
|---|---|---|---|---|---|
| ASL | Asia LDC | IDN | Indonesia | ROW | Rest of World |
| AUS | Australia | IND | India | RUS | Russian Federation |
| BRA | Brazil | JPN | Japan | SEA | Southeast Asia |
| CAN | Canada | KOR | Korea, Republic of | SSL | Sub-Saharan Africa LDC |
| CHN | China | LAC | Latin America | SSO | Sub-Saharan Africa other |
| E27 | European Union 27 | MEX | Mexico | TUR | Türkiye |
| EFT | EFTA | MIN | Middle East and North Africa | USA | United States of America |
| GBR | Great Britain | OAS | Other Asian countries | ZAF | South Africa |

EREGs are not a separate sector in the GTAP Data Base. Therefore, we have to generate EREGs as a separate sector. We employ Splitcom to split each of the 9 manufacturing sectors in our aggregation into three subsectors: EREGs, EPPs and a residual, targeting trade shares on EREGs. Then, the values for EREGs and EPPs are summed into values for respectively EREGs and EPPs. The list of HS lines constituting EREGs is put together for analytical and research purposes by the WTO.

Bilateral tariff rates for EREGs and EPPs are obtained from the Market Access Map (MAcMap) database, provided by the International Trade Centre (ITC). Ad-valorem equivalents of non-tariff measures (NTMs) are taken from Cadot et al. (2018) which are based on count data on NTMs from the UNCTAD TRAINS Data Base.

### 3.3 Modelling and Calibration of Emission Effects

In the model trade liberalization in EREGs has an impact on CO2 emissions along three channels. In this section we will discuss how these channels are modelled and how the parameters underlying the channels are calibrated.

First, trade liberalization in EREGs is projected to raise trade and income which will raise the demand for energy and thus emissions (scale effect). This channel emerges endogenously in the model, since emissions are proportional to the burning of fossil fuels. Since trade liberalization increases output it will also raise the demand for fossil fuels leading to larger emissions.

Second, increased imports of EREGs are projected to increase the energy efficiency of both production -less energy inputs are required to produce the same amount of output- and consumption -the same amount of goods can be consumed using less energy inputs , which will reduce the consumption of energy and thus emissions (technique effect). To model this channel, energy efficiency of both production and consumption is a function of the output price of EREGs which serve as an input in production. For production the following equation is added:

$$afa(c,a,r) = (..) + IF[c\ in\ ENY, EGAC(a) * EGAE(r) * (p_{fat}(''EGA'',a,r) - p_{fatwld})] \quad (1)$$

where $afa\,(c,a,r)$ is the energy efficiency of intermediate $c$ in activity $a$ which is shocked only for energy inputs in the set $ENY$, $p_{fat}(''EGA'',a,r)$ is the output price of EREGs, EGAE a vector of country-specific coefficients calibrated to to match the empirically estimated impact of imports of EREGs on CO2 emissions in a global panel of emissions and trade. [21]

Hence, energy efficiency $afa\,(c,a,r)$ is higher when the output price of EREGs, $p_{fat}(''EGA'',a,r)$, is lower. The impact of the price of EREGs on productivity only holds for energy inputs,

[21] $EGAC$ is a dummy variable equal to one for all sectors except for the sector "*Oil_Pcts*", i.e., petroleum and coal products since the scope for improved energy efficiency in oil refining in this sector is negligible and therefore cautiously the improvement in energy efficiency in this sector is omitted.

i.e. for $c$ in $ENY$.The elasticity of energy efficiency with respect to the price of EREGs in region $r$, $EGAE\,(r)$, is calibrated based on country-specific econometric estimates of the impact of imports of EREGs on CO2 emissions in a global panel of emissions and trade.[22]

To obtain the elasticity of emissions with respect to trade in environmental goods, we follow the approach pioneered by Baghdadi et al. (2013). It consists in regressing the logarithm of CO2 emissions, sourced from EDGAR database, on the logarithm of the import value of environmental goods. Following Baghdadi et al. (2013), Zugravu-Soilita (2018), and Zugravu-Soilita (2019) , we use a set of control variables such as the GDP, the capital-labour ratio (K/L), the gross national income (GNI) per capita, and trade openness. Endogeneity issues might still be present due to unobserved characteristics at country level that affect the level of emissions, other than trade in environmental goods, leading to an upward bias. Another source of endogeneity could be reverse causality, in which case the level of emissions could affect trade in environmental goods. To deal with such issues, we instrument the GNI per capita trade in environmental goods, and trade openness by their lagged variable. Global results of both OLS (column 1) and IV (column 2) regressions are presented in Table 4. All control variables have the expected sign and are statistically significant. The coefficient of environmental goods imports is statistically significant, negative, and close in magnitude for both regressions. The estimated coefficient of the pooled estimation suggests a decrease of 0.2% of CO2 emissions for a 1% increase in EREGs trade.

In addition, we estimate the impact of EREG imports on CO2 emissions by region. To obtain a regional coefficient, we use a similar approach than for the global results presented in table 4 but interact EREG imports with a regional dummy. Table A-3 reports the results of this regression, both for OLS and IV regressions. The reported coefficients on each region represents the total effect (i.e., the effect of the log of imports and the effect of the interaction). As for the global results, the values of the controls all have expected sign,

[22]The elasticity of energy efficiency with respect to (wrt) the price of gross output of EREGs is calibrated by simulating step-wise (from 1% to 10%) reductions in iceberg trade costs country-by-country, controlling for changes in GDP, for various levels of the elasticity. The simulated reductions in emissions are regressed on the simulated changes in real imports for various levels of the elasticity of energy efficiency with respect to the price of gross output, searching for the elasticity generating an elasticity of emissions with respect to trade equal to the empirically estimated elasticity. This calibration exercise generates an elasticity of energy efficiency with respect to the gross output price of EREGs of 0.4.

Table 4: Estimation results EG imports on CO2 emissions

| Dependant variable | ln(CO2) (OLS) | ln(CO2) (IV) |
|---|---|---|
| Ln(GDP) | 1.312*** | 1.427*** |
| | (0.043) | (0.059) |
| Ln(K/L) | 0.561*** | 0.524*** |
| | (0.037) | (0.040) |
| Ln(GNI per capita) | -0.800*** | -0.776*** |
| | (0.033) | (0.037) |
| Ln(Openness) | 1.318*** | 1.435*** |
| | (0.045) | (0.060) |
| Ln(Import EG) | -0.223*** | -0.325*** |
| | (0.040) | (0.054) |
| Obs | 1898 | 1742 |
| Adj. R2 | 0.895 | 0.886 |

Note: The dependant variable is the logarithm of CO2 emissions. The level of significance is: *** p < 0.01, ** p<0.05, * p<0.1

are statistically significant, and are of similar magnitude than those presented in table 4. Turning to the regional coefficients, the coefficients all exhibit the expected sign and most are statistically significant. The values of the estimates show some heterogeneity, with the statistically significant coefficients ranging from -0.128 (SSO) to -0.898 (GBR).

The estimated elasticity of CO2 emissions with respect to trade in EREGs is employed to calibrate the elasticity of energy efficiency with respect to the price of gross output of EREGs, $EGAE$. To calibrate we simulating reductions in iceberg trade costs step-wise (from 1% to 10%) country-by-country, controlling for changes in GDP, for various levels of the elasticity, $EGAE$. The simulated reductions in emissions are regressed on the simulated changes in real imports for various levels of $EGAE$, searching for the elasticity generating an elasticity of emissions with respect to trade equal to the empirically estimated elasticity. As a result the calibrated $EGAE$ varies across regions between 0.1 and 1.2.

Third, increased imports of EREGS, of which clean and renewable energy goods (CREs) are important components, are projected to reduce the costs of production in renewable energy sectors (i.e. Solar and Wind), leading to a substitution from the use of fossil fuels to renewable energy in electricity generation, which will reduce CO2 emissions (composition effect). The costs of producing renewable energy are affected in two different ways by the price of EREGs: (i) through the price of EREG intermediates used in production and; (ii) through the price of EREG capital goods. The latter channel is most important since the renewable energy sector is very capital intensive Chepeliev (2020).

However, the capital goods price channel does not emerge endogenously in the model, because investment is not sector specific in the employed model. Therefore, the price reduction of CREs is mapped into a productivity shock of capital in the different electricity sectors such as OilE, WindE, and SolarE. The productivity shock is set equal to the reduction of the price of sectoral investment in sector CRE multiplied by the share of CRE intermediates in total costs.

As in Hu et al. (2020), there is a possibility that lower prices of CRE goods also lead to lower costs in the production of electricity with non-renewable sources of energy (coal, oil, gas). Hence, a distinction is made between a scenario with end use control (i.e. only the costs of capital inputs in renewable energy sources of electricity is falling) and a scenario without end use control (i.e. the costs of capital inputs in all energy sources of electricity is falling). Hence, with end use control only the productivity of renewable energy sources of electricity is affected, whereas without end use control the productivity of all sources of electricity is affected.

### 3.4 Scenarios and descriptive evidence

In this study we consider four potential trade liberalization scenarios which are cumulative:

1. Elimination of tariffs on EREGs.
2. As (1) and a 25% reduction of NTMs on EREGs.
3. As (2) and elimination of tariffs on EPPs.
4. As (3) and a 25% reduction of NTMs on EPPs.

In the Scenario 1 only tariffs on EREGs are eliminated and thus reduced to zero.[23] In Scenario 2, we also reduce NTMs by 25% in addition to tariff reductions. In Scenario 3,

[23] A thorny though important detail is that baseline tariffs between the US and China are much higher since the 2018-2019 trade conflict between the two countries, also for EREGs and EPPs (see for example Bekkers and Schroeter (2020) for details on the US-China trade conflict and the tariffs imposed). To avoid taking a stance on the likelihood of these tariffs being reduced and to avoid that reduction of these tariffs would dominate the simulation outcomes, the simulation results presented do not take these tariffs into account. This means that results can be interpreted as if they are either projecting the change in trade flows compared to the situation before the US-China trade conflict or they are assuming that the US-China tariff increases from 2018-2019 stay in place.

the elimination of tariffs on EPPs is added and finally in Scenarios 4 tariffs are eliminated and NTMs reduced by 25% on both EREGs and EPPs.

We assume that the trade costs because of NTMs (more formally the ad valorem equivalents, AVEs) fall by 25%. We work with a moderate 25% since many NTMs serve domestic policy objectives and can thus not be reduced and some NTMs are not necessarily trade restrictive. A 25% reduction in NTMs is also in line with empirical estimates of the effect of FTAs on NTMs (Porto (2018), Francois et al. (2015)).

Table 5 displays respectively per importer and per exporter the assumed percentage point changes in ad-valorem tariffs and trade costs associated with NTMs for Scenario 4 (full liberalization).[24] The table makes clear that initial tariffs (and thus tariff cuts) are lowest for developed countries as importer, followed by developing and least developed countries.[25] For NTMs the pattern is opposite: they are cut most for developed economies, although the differences are smaller than for tariffs. Globally, the reductions in NTMs and tariffs are similar in the trade liberalization scenarios. On the exporter side least-developed countries would face the smallest reduction in tariffs, which is related to the existence of preferential tariff rates already in place.

Table 5: Percentage point changes in the ad valorem equivalent tariffs and NTMs for EREGs and EPPs for groups of countries

| Region | Commodity: EGA | | Commodity: EPP | |
|---|---|---|---|---|
| | AVE Tariff Cut | AVE NTM Cut | AVE Tariff Cut | AVE NTM Cut |
| | | Importer | | |
| Developed | 0.71% | 1.96% | 1.41% | 2.58% |
| Developing | 2.77% | 1.51% | 4.08% | 1.87% |
| Least-developed | 6.68% | 1.11% | 7.68% | 2.20% |
| Global (WLD) | 1.61% | 1.74% | 2.93% | 2.24% |
| | | Exporter | | |
| Developed | 1.67% | 1.73% | 1.96% | 2.24% |
| Developing | 1.70% | 1.78% | 3.14% | 2.28% |
| Least-developed | 0.81% | 1.66% | 2.21% | 2.51% |

Notes: the table displays the percentage point changes in the tariff rates and ad valorem rates of NTMs in the EREG and EPP liberalization scenarios per exporter and importer for three groups of countries. Developing is exclusive of the least-developed economies.
Source: MacMap ITC and GTAP Data Base

Table 6 displays the value of trade for 2021 in EREGs and EPPs per region, as well as

[24]Since the scenarios are cumulative, this table also provides all information about trade cost reductions in Scenarios 1-3.

[25]The percentage point tariff and NTMs changes for all regions are in Annex Tables A.1 and A.2.

the revealed comparative advantage (RCA) of regions in these goods.[26] The table makes clear that China is both in absolute (trade share) and relative terms (RCA) an important player in EREGs. The table shows that comparative advantage in EREGs is concentrated in Asia: Japan, Korea, Republic of, Other Asia (OAS), and South-East Asia (SEA) all have an RCA larger than 1 in these goods. Low-income regions such Asia Least-Developed (ASL), Sub-Saharan Africa Least Developed (SSL) and Sub-Saharan Africa Other (SSO) instead have a very low RCA in EREGs. For EPPs the picture is different: most low-income regions have a comparative advantage in these products (ASL, Indonesia, India, SSL, and SSO), although also SEA is an important player in these products. Finally, Table 2 shows that trade in EREGs is an order of magnitude larger than trade in EPPs, respectively 2 trillion and 67 billion dollars.

[26]The Table displays 2021 projected values based on our model, before counterfactual experiments are introduced.

Table 6: The share of exports to different regions in global trade of EREG and EPP and the revealed comparative advantage in EREGs and EPPs

| Regions | Share of exports in global trade | | RCA | |
|---|---|---|---|---|
| | EREG | EPP | EREG | EPP |
| ASL | 0.1% | 1.4% | 0.10 | 2.75 |
| AUS | 0.3% | 5.0% | 0.21 | 3.19 |
| BRA | 0.5% | 0.8% | 0.30 | 0.51 |
| CAN | 1.6% | 1.1% | 0.60 | 0.44 |
| CHN | 23.8% | 15.1% | 1.82 | 1.15 |
| E27 | 24.4% | 22.5% | 0.86 | 0.80 |
| EFT | 1.7% | 0.9% | 0.65 | 0.35 |
| GBR | 1.5% | 1.6% | 0.56 | 0.57 |
| IDN | 0.7% | 6.9% | 0.59 | 5.59 |
| IND | 1.0% | 2.3% | 0.52 | 1.20 |
| JPN | 7.6% | 2.3% | 1.90 | 0.57 |
| KOR | 7.5% | 1.3% | 2.26 | 0.39 |
| LAC | 0.8% | 3.8% | 0.27 | 1.36 |
| MEX | 2.3% | 0.4% | 1.21 | 0.22 |
| MIN | 1.6% | 1.5% | 0.25 | 0.23 |
| OAS | 4.7% | 2.3% | 1.27 | 0.61 |
| ROW | 0.6% | 0.7% | 0.37 | 0.45 |
| RUS | 0.5% | 0.4% | 0.19 | 0.14 |
| SEA | 10.3% | 23.2% | 1.70 | 3.84 |
| SSL | 0.0% | 0.8% | 0.05 | 1.01 |
| SSO | 0.2% | 1.1% | 0.16 | 1.21 |
| TUR | 0.5% | 0.8% | 0.61 | 0.96 |
| USA | 7.6% | 2.7% | 0.93 | 0.33 |
| ZAF | 0.2% | 0.8% | 0.43 | 1.56 |
| WLD | 2,030,952 | 67,476 | | |

Source: MacMap ITC and GTAP Data Base

# 4 Results

In this section the projected medium-run effects of trade liberalization in EREGs and EPPs on trade, GDP and emissions by 2030 are presented. [27] The projections are based on the four scenarios defined in the previous section.

## 4.1 Trade Effects

The projected per cent changes in real exports of EREGs (upper panel) and EPPs (lower panel) in different regions are displayed in Figure 1 for Scenario 4, whereas Table 7 contains the projected changes in the quantity of exports in millions of dollars. There are four takeaways from these results. First, global exports of both EREGs and EPPs are projected to increase respectively by 5% and 14% (Region WLD in the Figure 1) under the trade liberalization scenario. Second, the projected per cent change in exports is larger for EPPs than for EREGs, although the value of trade of the latter is much larger. Table 7 shows that at the global level the projected expansion of trade in EREGs in millions of dollars is an order of magnitude larger than the increase in trade of EPPs. However, behind these aggregate numbers there are substantial shifts in bilateral market shares as a result of trade shifting.

Third, exports of EPPs from most regions are expected to increase, whereas exports of EREGs are projected to rise only in slightly more than half of the regions. Low-income regions are projected to expand trade of EPPs, whereas trade gains of EREGs are concentrated in the high-income and Asian regions. Table 7 shows that more than 80% of the projected increase in the quantity exported by 2030 in millions of dollars occurs in three countries: China, Japan, and the Republic of Korea. The concentration of export gains in these three regions can also explain why some regions are projected to see their exports of EREGs decrease. The source of imports into big markets like to EU for example is projected to shift to China, leading to trade diversion away from other regions. We analyze three countries into more details. Table A.5 displays the initial value of exports, the simulated tariff reductions, and the projected changes in exports from Southeast Asia to

[27] As discussed in the introduction, emission effects of substitution towards EPPs are not modelled because of a lack of data on emissions at the detailed product level.

Table 7: The projected change in the quantity of exports of EREGs, EPPs, and total exports by 2030 in millions of dollars

| Region | EREG | EPP | Total |
|---|---|---|---|
| ASL | -105 | 11 | 486 |
| AUS | 424 | -316 | 1281 |
| BRA | 614 | 81 | 7084 |
| CAN | 859 | 104 | 1238 |
| CHN | 60917 | 4015 | 47898 |
| E27 | 9564 | 1247 | 6782 |
| EFT | 611 | 267 | 106 |
| GBR | 883 | 96 | 412 |
| IDN | -225 | 498 | 539 |
| IND | 2989 | 336 | 9338 |
| JPN | 15469 | 466 | 4713 |
| KOR | 17025 | 254 | 11972 |
| LAC | -1336 | 42 | 2943 |
| MEX | -303 | 101 | 104 |
| MIN | -314 | 127 | 11288 |
| OAS | 3606 | 127 | 1913 |
| ROW | -502 | 89 | 974 |
| RUS | -91 | 3 | 3294 |
| SEA | -5832 | 2185 | 2373 |
| SSL | -38 | 83 | 960 |
| SSO | -396 | 88 | 1889 |
| TUR | 1644 | 67 | 287 |
| USA | 4774 | 452 | 10959 |
| ZAF | -232 | -27 | 633 |
| **WLD** | **110005** | **10395** | **129465** |

Source: simulations GTM

other regions. Southeast Asia is selling a large share of its exports to China (26%). At the same time, the initial tariffs in EREGs is 0%. Given that other regions would see tariffs into China fall under the liberalization scenario (see Table A-8) , trade diversion away from goods coming from Southeast Asia would be the result. Exports from Southeast Asia to some other regions are projected to increase at some extent (particularly to Japan and the USA), but this increase is insufficient to compensate the projected loss of sales in China. Southeast Asia's exports would also fall to some other destinations, particularly Southeast Asia itself, which can again be attributed to trade diversion effects.

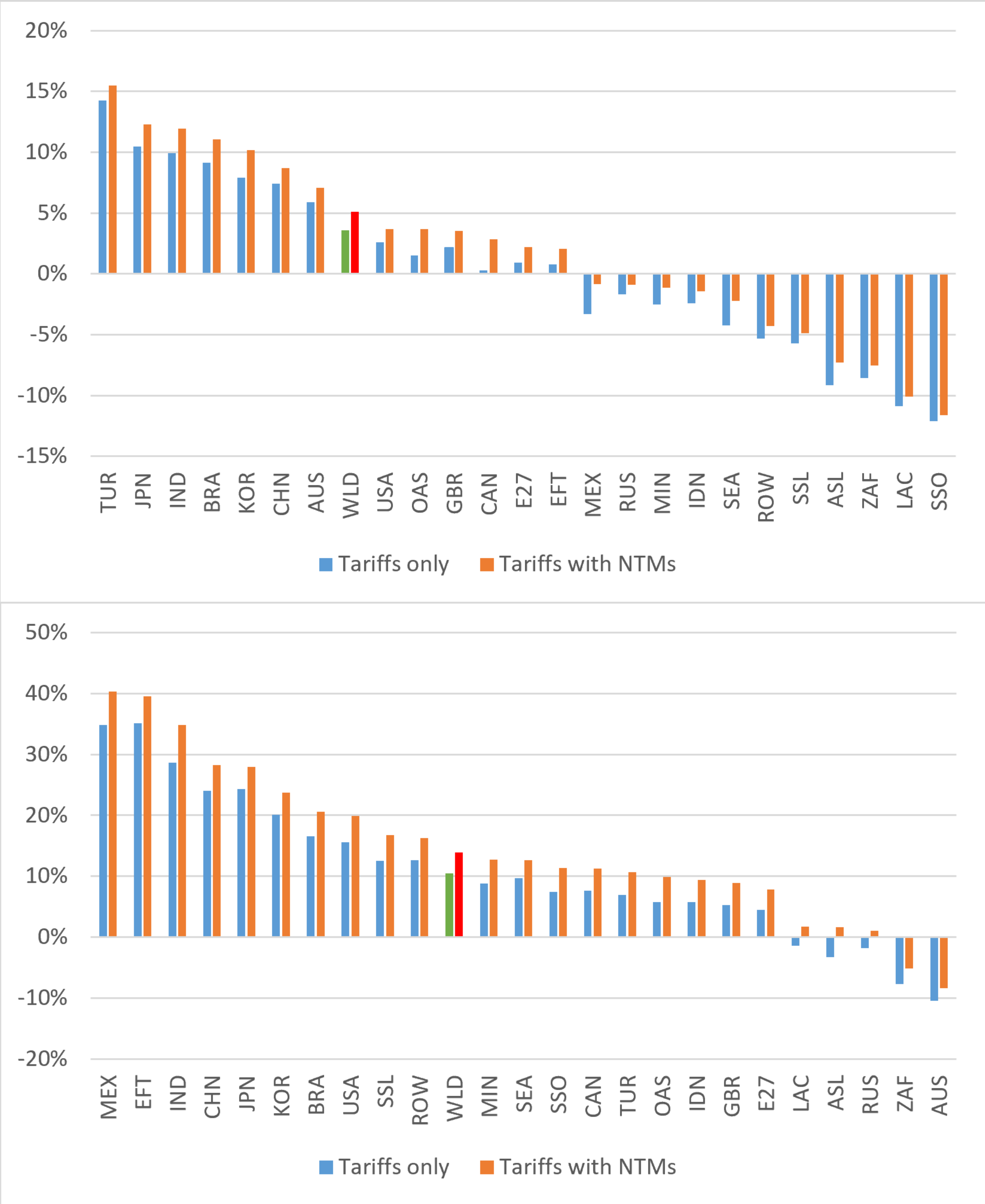
Table A-7 shows the projected changes in China's exports. The largest increases in exports are expected to the large destination markets E27, USA, and also the Republic of Korea. Also exports to Brazil are projected to rise substantially, because of relatively high initial tariffs. Table A-8 shows the projected changes in trade for China as importer. The table shows that the bulk of the projected increase in imports into China will come from the EU, Japan and the Republic of Korea, both because these regions have a substantial market share and because tariffs would fall substantially (3%-5%) for exports into China from these regions. As analyzed above the increase in imports from these regions would be at the expense of exports from Southeast Asia. Finally, Table A.8 A-8 displays the projected change in imports of EREGs into the EU. The table makes clear that changes here are dominated by shift in intra-EU trade to imports from China. Imports from China are projected to increase by 148% of the total increase in imports into the EU, whereas imports from within the EU (intra-EU trade) will fall by 82% of the total change in EU imports.

Fourth, total exports are projected to rise for all regions. This is because of the fall in trade costs of EREGs and EPPs and the implied increase in energy efficiency, both raising GDP and leading to an increase in import demand. This positive effect on trade dominates the negative effect of trade diversion for EREGs and EPPs in some regions.

## 4.2 Macroeconomic Effects

The projected per cent changes in real GDP for each of the regions in the simulations are displayed in Figure 2. The figure suggests that even the regions projected to face a

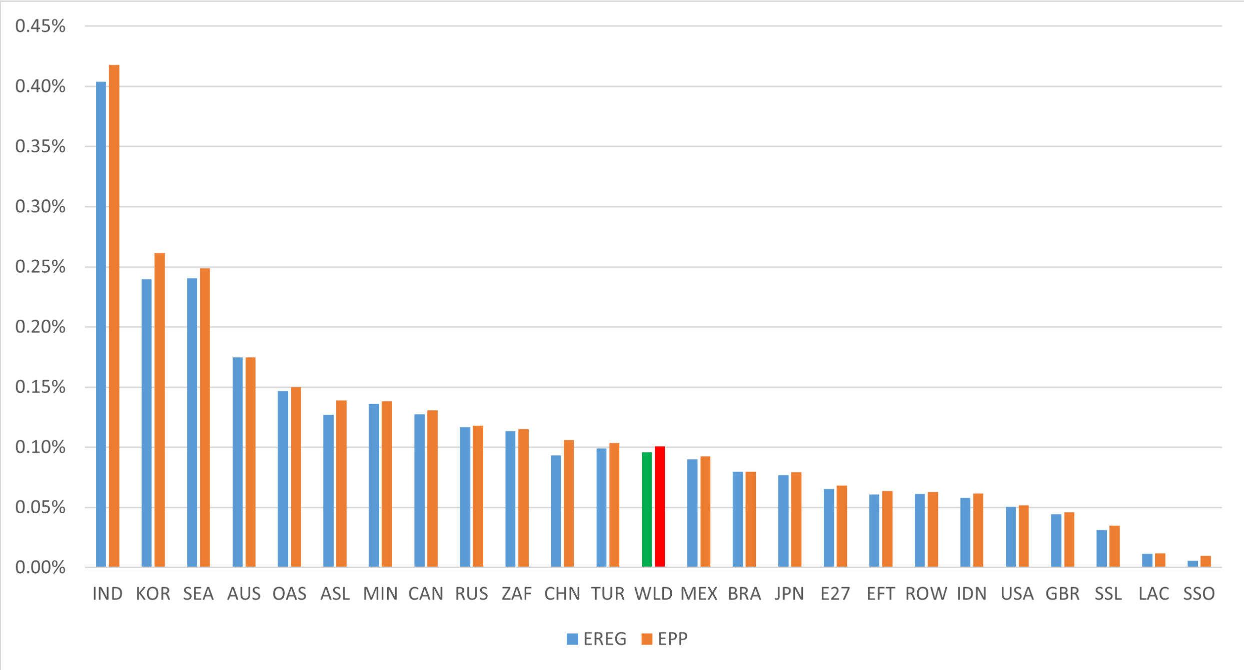
Figure 1: Projected per cent change in real exports of EREG (upper panel) and EPP (lower panel) in 2030




Notes: The figure displays the projected per cent changes with the WTO Global Trade Model in exports of EREGs (upper panel) and EPPs (lower panel) with only a reduction in tariffs (blue bars) and a reduction in both tariffs and NTMs (red bars), based on the reductions displayed in Annex Tables A-4 and A-5

fall in real exports of EREGs and EPPs because of trade diversion (as shown in Figure 1 and discussed in the previous sub-section) are expected to see their real GDP increase,

Figure 2: Projected per cent change in real GDP by region




Notes: The figure displays the projected per cent changes with the WTO Global Trade Model in GDP with only tariff and NTMs reductions of EREGs and both EREGs and EPPs.

which can be explained by three forces. First, the reduction in tariffs and NTMs of EREGs and EPPs reduces distortions in the economy and thus raises output. Second, NTMs are resource-wasting regulations (modelled as iceberg trade costs) implying that reductions in NTMs operate like an increase in productivity: the costs of exporting fall because of a reduction in the resources exporters need to spend to be able to export.[28] This contributes to positive GDP effects. Third, the reduction in the price of EREGs leads to an increase in energy efficiency, constituting a second positive productivity effect. The three features imply that resource efficiency and productivity are projected to increase as a result of trade liberalization in EPPs (through lower tariffs and NTMs) and in particular EREGs (through both lower iceberg trade costs and higher energy efficiency), which in turn leads to a rise in GDP.

Figure 2 makes clear that most of the projected increase in real GDP is driven by trade liberalization of EREGs with EPPs trade liberalization only contributing little. The reason is that the projected change in trade in EPPs is an order of magnitude smaller than the

[28]For the products and NTMs modelled it is reasonable to assume that they are resource-wasting, because they concern mostly technical barriers to trade (TBTs) type of measures which require firms to spend extra resources to comply with them.

projected trade change of EREGs.

### 4.3 Emissions Effects

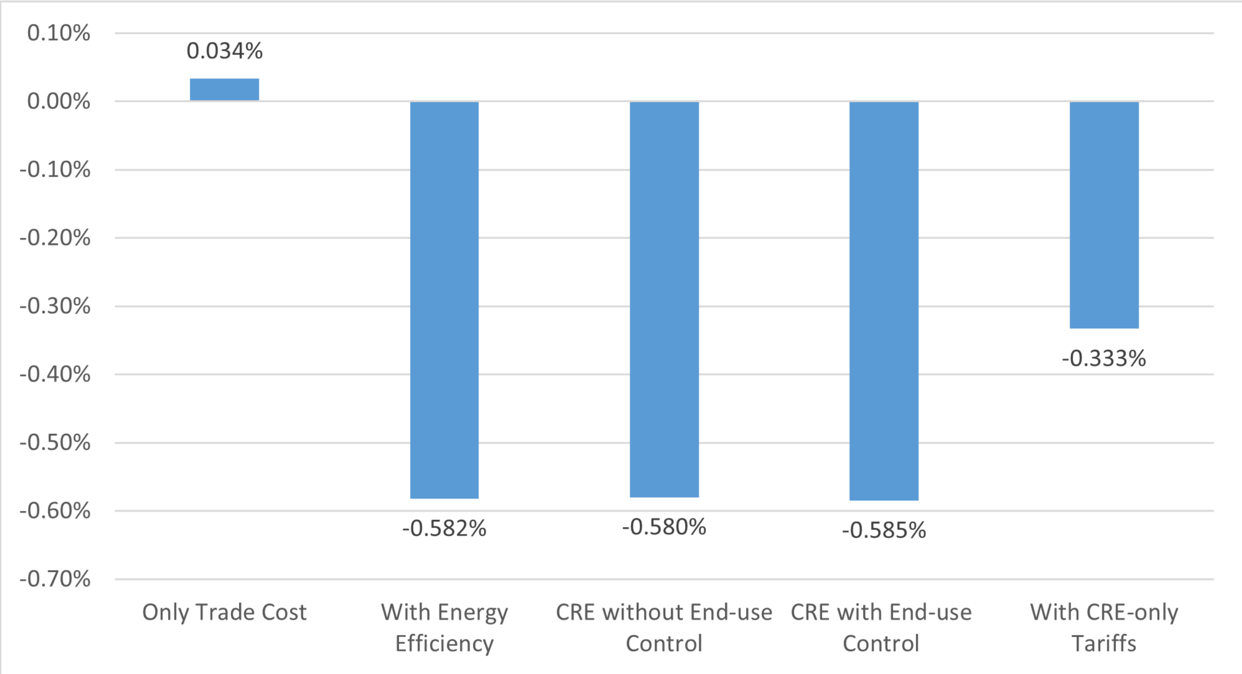
We now turn the analysis towards the projected change in emissions in the various scenarios. Figure 3 displays the projected reduction in global $CO_2$ emissions depending on the inclusion of the channels discussed in Section 3.1. The first bar considers only the scale effects driven by more demand for more fossil fuels because of expanded production, neglecting the impact on energy efficiency and the reduced price of investment goods used in the production of electricity. As expected, this channel is projected to lead to an increase in global emissions, because lower trade costs will raise income and thus increase the demand for energy.[29] The second bar includes the energy efficiency channel, turning the effect of a potential trade liberalization in EREGs on $CO_2$ emissions negative. The simulations indicate that emissions would fall by about 0.6% globally by 2030. Indeed, higher energy efficiency because of cheaper availability of goods employed to raise energy efficiency will reduce the use of energy by both firms and households. Hence, less energy is needed for the same amount of production. However, the impact on the reduction of emissions is tempered by a so-called rebound effect: higher energy efficiency will reduce the price of energy as input into the production process and thus increase the demand for energy leading to more emissions.[30] The third and fourth bar include the effect of a lower price of investment goods of clean and renewable energy (CRE) goods used in the electricity sectors (captured by a productivity increase of capital use in these sectors). The third bar displays the effects without end use control and the fourth with end use control. Without end use control the productivity of capital in all electricity generating sectors rises, whereas with end use control only the productivity of electricity sectors generating electricity from renewable sources is increasing.

The simulations indicate that the last channel, as expected, leads to a smaller reduction in emissions without end use control and a slightly larger reduction with end use

[29]Part of the effect is also driven by increased demand for transportation services, which generates additional emissions.

[30]Higher energy efficiency corresponds with an increase in productivity of energy inputs thus decreasing its price.

Figure 3: Projected per cent change in global CO2 emissions with different channels

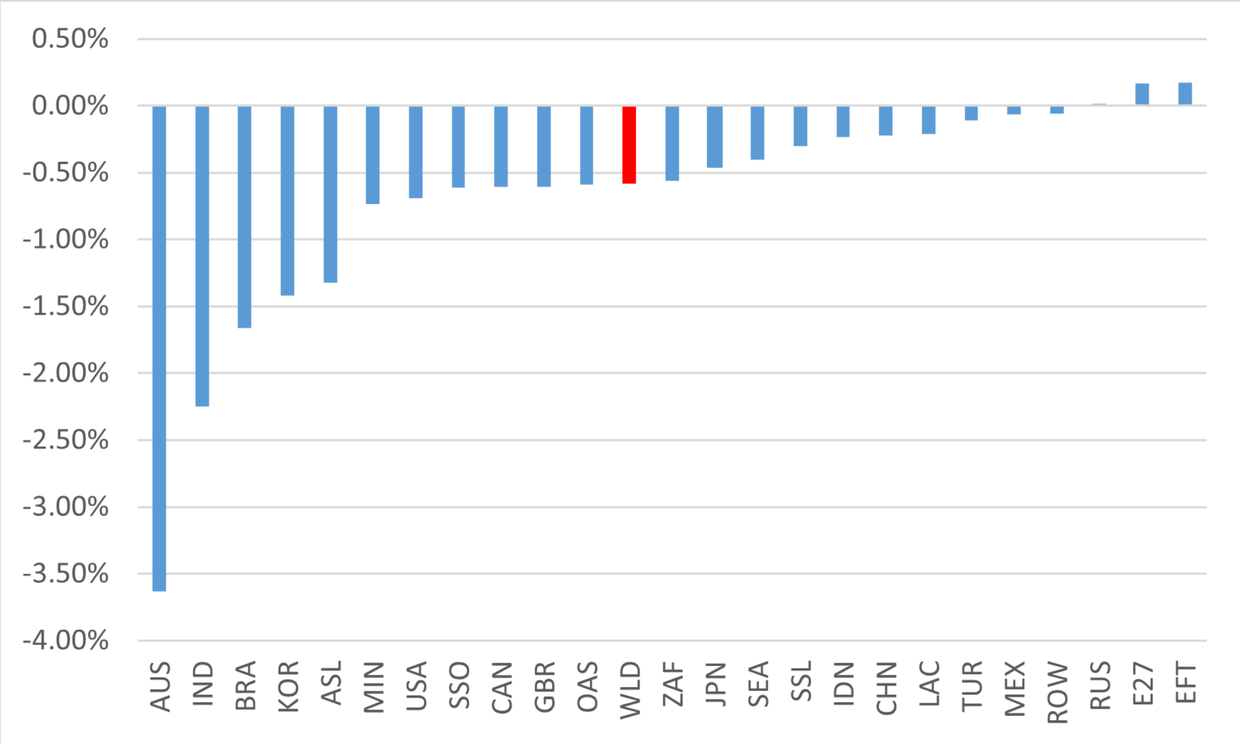



Notes: The figure displays the projected per cent changes in global CO2 emissions with the WTO Global Trade Model in GDP according to the different channels included. The first bar includes only the impact of trade cost reductions. The second bar includes the energy efficiency channel. The third and fourth bar include the impact of a reduction in the price of investment goods used in electricity generating sectors because of increased imports of CRE goods. The fifth bar includes all channels (CRE with end use control), but only models a reduction in tariffs.

control. With end use control, the production of electricity from renewable energy sources becomes cheaper, leading to a substitution from electricity generated from fossil fuel to electricity generated from renewable sources, thus reducing emissions. Without end use control, the production of electricity based on all sources becomes cheaper, leading to higher emissions. However, the size of this channel as well as the effect of end-use control are small. Emissions with end use control fall by about 0.003% more and without end use control they fall by about 0.003% less.[31] The fifth bar displays the effect considering all channels (i.e. lower prices of CRE goods with end-use control), but only based on tariff liberalization. The projected reduction in emissions in this scenario is about half the reduction compared to the scenario with a reduction in both tariffs and NTMs.

[31]Compared with Hu et al. (2020) the CRE channel in this study is about an order of magnitude smaller, since the projected reduction in emissions in their study is 0.12%. This can be explained by three main differences between the two approaches. First, in Hu et al. (2020) the reduction in the price of CRE goods is based on an external PE model. Second, it is assumed that the same price reduction applies for domestic goods, whereas in the current study the domestic price of CRE goods follows from simulations with the model. Second, in the current study a recursive dynamic CGE model is employed to simulate the impact on CO2 emissions, whereas Hu et al. (2020) use an energy model.

Figure 4: Projected per cent change in emissions per region in tariff and NTM scenario




Notes: The figure displays the projected per cent changes in regional CO2 emissions with the WTO Global Trade Model with all the channels included (CRE with end use control).

Finally, Figure 4 displays the projected change in emissions in the different regions in the scenario with both tariff and NTMs reductions (Scenario 4). Emissions in all regions except for European Free Trade Association (EFTA) countries are projected to fall.[32] However, rather than the geographical pattern of changes in emissions, what matters for climate change mitigation is the global change in emissions.

# 5 Conclusion

In this paper we discussed the potential impact of trade liberalization in environmental goods on trade patterns, GDP, and emissions. Reductions in both tariffs and NTMs on two types of environmental goods, energy related environmental goods (EREGs) and environmentally preferable products (EPPs) have been simulated with the power version

[32]The reason for the projected increase in emissions in EFTA is that in EFTA Norway is exporting a substantial share of its electricity. This implies that an improvement in energy efficiency will raise the demand for electricity thus raising emissions from production of electricity in the EFTA region. However, such inter-country substitution effects in the demand for electricity do not significantly affect the projected global reduction in emissions.

of the WTO Global Trade Model. The simulations project:

(i) an increase in exports of EREGs and EPPs in most regions as well as an increase in aggregate exports in all regions. (ii) a modest increase in GDP in all regions as a result of falling tariffs, NTMs, and increased energy efficiency. (iii) a modest reduction in global emissions of about 0.3

Emissions are expected to be affected through three different channels by a potential EGA: (1) through an increase in energy efficiency because of the increased availability and reduced prices of energy and resource efficiency goods, emissions are projected to fall; (2) through a reduction in the price of clean and renewable energy goods reducing the costs to produce electricity from renewable energy sources, emissions are expected to fall; (3) through rising income and trade, emissions are expected to increase because of a rising demand for energy. The first two effects drive down emissions and the third raises emissions. The simulations show that the first effect is much larger than the second effect and that the negative effects dominate the positive effects implying a projected reduction in emissions. The fact that the second channel is small in our projections also implies that end-use control is less important for guaranteeing a reduction in emissions because of trade liberalization in environmental goods.

However, this study comes with some limitations. Two ways in which emissions could be affected are not incorporated in the simulations. First, increased trade in environmental goods can promote the diffusion of green innovation, and second, liberalization of EPPs can lead to a shift of consumption to environmentally preferable goods with lower emissions. For the diffusion of green innovation channel end use control could be important, since technology also diffuses with trade for fossil fuel technologies. However, both channels are hard to quantify. In particular, a lack of emissions data at the detailed sectoral level makes it difficult to evaluate the emissions effects of trade in EPPs.

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# Appendix A

# 1 Additional Tables

Table A-1: Region aggregation

| Code | Description | Countries |
|---|---|---|
| ASL | Asia LDC | Cambodia, Lao People's Democratic Republic, Rest of Southeast Asia, Bangladesh, Nepal |
| AUS | Australia | Australia |
| BRA | Brazil | Brazil |
| CAN | Canada | Canada |
| CHN | China | China |
| E27 | European Union 28 | Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden |
| EFT | EFTA | Switzerland, Norway, Rest of EFTA |
| GBR | Great Britain | United Kingdom |
| IDN | Indonesia | Indonesia |
| IND | India | India |
| JPN | Japan | Japan |
| KOR | Korea | Korea, Republic of |
| LAC | Latin America | Rest of North America, Argentina, Bolivia, Plurinational State of, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Bolivarian Republic of, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Caribbean |
| MEX | Mexico | Mexico |
| MIN | Middle East and North Africa | Bahrain, Kingdom of, Iran Islamic Republic of, Israel, Jordan, Kuwait, the State of, Oman, Qatar, Saudi Arabia, Kingdom of, United Arab Emirates, Rest of Western Asia, Egypt, Morocco, Tunisia, Rest of North Africa |
| OAS | Other Asian countries | New Zealand; Rest of Oceania; Hong Kong, China; Mongolia; Chinese Taipei; Rest of East Asia; Pakistan; Sri Lanka Rest of South Asia |
| ROW | Rest of World | Albania, Belarus, Ukraine, Rest of Eastern Europe, Rest of Europe, Kazakhstan, Kyrgyz Republic, Tajikistan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Rest of the World |
| RUS | Russia | Russian Federation |
| SEA | Southeast Asia | Brunei Darussalam, Malaysia, Philippines, Singapore, Thailand, Viet Nam |
| SSL | Sub-Saharan Africa LDC | Benin, Burkina Faso, Guinea, Togo, Rest of Western Africa, South Central Africa, Ethiopia, Madagascar, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa |
| SSO | Sub-Saharan Africa other | Cameroon, Côte d'Ivoire, Ghana, Nigeria, Senegal, Central Africa, Kenya, Mauritius, Botswana, Namibia, Rest of South African Customs |
| TUR | Türkiye | Türkiye |
| USA | United States of America | United States of America |
| ZAF | South Africa | South Africa |

Note: Authors' compilation.

## Table A-2: Sectoral aggregation

| Code | Description | Old sectors |
|---|---|---|
| Agriculture | Agriculture | Paddy rice; Wheat; Cereal grains nec; Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Bovine cattle, sheep and goats; Animal products nec; Raw milk; Wool, silk-worm cocoons; Forestry; Fishing. |
| Coal | Coal | Coal. |
| Oil | Oil | Oil. |
| Gas | Gas | Gas; Gas manufacture, distribution. |
| Oil_Pcts | Petroleum and coal | Petroleum, coal products. |
| chm | Chemicals | Chemical products. |
| prp | Pharmaceuticals, rubber and pl | Basic pharmaceutical products; Rubber and plastic products. |
| ele | Computer, electronic and optic | Computer, electronic and optic. |
| eeq | Electrical equipment | Electrical equipment. |
| ome | Machinery and equipment nec | Machinery and equipment nec. |
| mvh | Motor vehicles and parts | Motor vehicles and parts. |
| otn | Transport equipment nec | Transport equipment nec. |
| Oth Ind | Other Industries | Bovine meat products; Meat products nec; Vegetable oils and fats; Dairy products; Processed rice; Sugar; Food products nec; Beverages and tobacco products; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Metal products; Manufactures nec. |
| En Int Ind | Energy intensive industries | Minerals nec; Mineral products nec; Ferrous metals; Metals nec. |
| EREGs | Energy related environmental goods | Parts of sectors Chemicals until Energy Intensive Industries |
| EPP | Environmentally Preferable Products | Parts of sectors Chemicals until Energy Intensive Industries |
| TnD | Electricity: Transmission and | Electricity: Transmission and . |
| NuclearE | Nuclear electricity | Nuclear base load. |
| CoalE | Coal electricity | Coal base load. |
| GasE | Gas electricity | Gas base load; Gas peak load. |
| WindE | Wind electricity | Wind base load. |
| HydroE | Hydro electricity | Hydro base load; Hydro peak load. |
| OilE | Oil electricity | Oil base load; Oil peak load. |
| OthE | Other electricity | Other base load. |
| SolarE | Solar electricity | Solar peak load. |
| Services | Services | Water; Construction; Trade; Accommodation, Food and service; Warehousing and support activities; Communication; Financial services nec; Insurance; Real estate activities; Business services nec; Recreational and other service; Public Administration and defe; Education; Human health and social work a; Dwellings. |
| Transport | Transport | Transport nec; Water transport; Air transport. |

Note: Authors' compilation.

Table A-3: Estimation results EG imports on CO2 emissions by region

| | ln(CO2) (OLS) | ln(CO2) (IV) |
|---|---|---|
| Log GDP | 1.041*** | 1.101*** |
| | (0.0332) | (0.0512) |
| Log K/L | 0.349*** | 0.320*** |
| | (0.0310) | (0.0333) |
| Log GNI/pop | -0.594*** | -0.563*** |
| | (0.0301) | (0.0325) |
| Log Openness | 1.034*** | 1.097*** |
| | (0.0341) | (0.0514) |
| Ln(Import EG) by region (total effect): | | |
| ASL | -.3998*** | -0.490*** |
| | (.0486) | (0.0738) |
| AUS | -.3906*** | -.4361*** |
| | (.0456) | (.0628) |
| BRA | -.318*** | -.2915*** |
| | (.086) | (.1025) |
| CAN | -.2385*** | -.2812*** |
| | (.0385) | (.0456) |
| CHN | -.0547 | -.0844 |
| | (.04) | (.0553) |
| E27 | -.125*** | -.1852*** |
| | (.036) | (.0534) |
| EFT | -.2734*** | -.3377*** |
| | (.0431) | (.0581) |
| GBR | -.8639*** | -.8981*** |
| | (.0473) | (.0551) |
| IDN | -.2551*** | -.2788*** |
| | (.0403) | (.0476) |
| IND | -.4363*** | -.4932*** |
| | (.0482) | (.0652) |
| JPN | -.4037*** | -.4185*** |
| | (.062) | (.077) |
| KOR | -.3819*** | -.4431*** |
| | (.0443) | (.0646) |
| LAC | .0108 | -.0281 |
| | (.0402) | (.0554) |
| MEX | -.5580*** | -.5835*** |
| | (.0431) | (.0577) |
| MIN | -.2076*** | -.2554*** |
| | (.0415) | (.0535) |
| OAS | -.2652*** | -.3071*** |
| | (.0315) | (.0426) |
| ROW | .0347 | -.0057 |
| | (.0368) | (.0527) |
| RUS | -.2904*** | -.3369*** |
| | (.0374) | (.0542) |
| SAU | -.1961*** | -.2644*** |
| | (.0742) | (.0992) |
| SEA | -.3645*** | -.4221*** |
| | (.0573) | (.0673) |
| SSL | -.1111*** | -.165*** |
| | (.038) | (.0537) |
| SSO | -.0629* | -.128** |
| | (.0337) | (.0528) |
| TUR | -.4555*** | -.4718*** |
| | (.045) | (.0652) |
| USA | -.4398*** | -.4575*** |
| | (.0419) | (.0512) |
| ZAF | -.4927*** | -.5445*** |
| | (.0418) | (.0542) |
| Obs | 1883 | 1729 |
| Adj. R2 | 0.998 | 0.845 |

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A-4: Percentage point changes in trade barriers full liberalization scenario (per exporter)

| Region | Commodity: EGA | | Commodity: EPP | |
|---|---|---|---|---|
| | AVE Tariff Cut | AVE NTM Cut | AVE Tariff Cut | AVE NTM Cut |
| ASL | 0.33% | 1.75% | 2.42% | 2.50% |
| AUS | 2.28% | 1.64% | 1.39% | 1.63% |
| BRA | 2.41% | 1.61% | 2.19% | 2.35% |
| CAN | 0.91% | 1.95% | 1.40% | 2.23% |
| CHN | 2.31% | 1.81% | 5.72% | 2.34% |
| E27 | 1.10% | 1.80% | 1.61% | 2.25% |
| EFT | 1.24% | 1.76% | 2.69% | 2.39% |
| GBR | 1.35% | 1.82% | 2.35% | 2.38% |
| IDN | 0.86% | 1.87% | 2.15% | 2.58% |
| IND | 2.70% | 1.75% | 4.58% | 2.58% |
| JPN | 2.70% | 1.59% | 5.17% | 2.03% |
| KOR | 2.33% | 1.57% | 4.19% | 2.11% |
| LAC | 0.52% | 1.67% | 1.31% | 2.20% |
| MEX | 0.24% | 2.02% | 1.26% | 2.91% |
| MIN | 1.40% | 1.76% | 2.51% | 2.50% |
| OAS | 1.34% | 1.62% | 2.63% | 2.20% |
| ROW | 0.92% | 1.71% | 3.16% | 2.14% |
| RUS | 1.79% | 1.56% | 1.69% | 1.89% |
| SEA | 0.51% | 1.69% | 3.14% | 2.07% |
| SSL | 1.16% | 1.55% | 2.48% | 2.56% |
| SSO | 1.67% | 1.43% | 2.12% | 2.32% |
| TUR | 3.29% | 1.70% | 2.72% | 2.34% |
| USA | 1.64% | 1.74% | 3.24% | 2.84% |
| ZAF | 1.42% | 1.58% | 1.56% | 1.84% |
| WLD | 1.61% | 1.74% | 2.93% | 2.24% |

Note: Note: Authors' computation.

Table A-5: Percentage point changes in trade barriers full liberalization scenario (per importer)

| Region | Commodity: EGA | | Commodity: EPP | |
|---|---|---|---|---|
| | AVE Tariff Cut | AVE NTM Cut | AVE Tariff Cut | AVE NTM Cut |
| ASL | 5.96% | 1.40% | 4.58% | 2.87% |
| AUS | 2.01% | 2.83% | 1.30% | 2.78% |
| BRA | 11.15% | 3.03% | 6.17% | 2.36% |
| CAN | 0.46% | 2.27% | 1.06% | 6.08% |
| CHN | 2.59% | 1.33% | 4.82% | 1.05% |
| E27 | 0.64% | 1.78% | 0.58% | 2.24% |
| EFT | 0.03% | 1.72% | 0.20% | 2.46% |
| GBR | 0.86% | 2.13% | 0.84% | 2.48% |
| IDN | 1.66% | 0.85% | 1.73% | 1.82% |
| IND | 5.90% | 1.99% | 15.41% | 3.31% |
| JPN | 0.12% | 2.34% | 1.75% | 2.23% |
| KOR | 2.36% | 1.72% | 12.56% | 2.46% |
| LAC | 4.27% | 0.91% | 2.41% | 2.00% |
| MEX | 0.59% | 1.38% | 1.06% | 2.26% |
| MIN | 4.32% | 1.72% | 3.81% | 2.46% |
| OAS | 0.91% | 1.50% | 1.33% | 1.60% |
| ROW | 2.81% | 1.09% | 2.71% | 1.26% |
| RUS | 3.27% | 1.72% | 4.21% | 2.46% |
| SEA | 0.90% | 1.56% | 1.05% | 1.79% |
| SSL | 7.14% | 0.93% | 12.55% | 0.88% |
| SSO | 8.64% | 0.63% | 7.20% | 3.13% |
| TUR | 0.37% | 2.70% | 1.01% | 3.46% |
| USA | 0.66% | 2.10% | 1.06% | 3.05% |
| ZAF | 2.04% | 1.72% | 1.80% | 2.46% |
| WLD | 1.61% | 1.74% | 2.93% | 2.24% |

Note: Authors' computation.

Table A-6: The initial value of exports, simulated tariff reduction, and projected change in exports from Southeast Asia

| Region | Exports value | Exports share | Tariff reduction | Change exports value | Change exports share |
|---|---|---|---|---|---|
| ASL | 2019 | 1% | 2% | -508 | 6% |
| AUS | 2394 | 1% | 0% | -297 | 3% |
| BRA | 1168 | 1% | 8% | -40 | 0% |
| CAN | 2041 | 1% | 0% | -40 | 0% |
| CHN | 51719 | 25% | 0% | -5376 | 61% |
| E27 | 23815 | 11% | 1% | 43 | 0% |
| EFT | 904 | 0% | 0% | 10 | 0% |
| GBR | 2076 | 1% | 1% | -19 | 0% |
| IDN | 5154 | 2% | 0% | -421 | 5% |
| IND | 5113 | 2% | 4% | 152 | -2% |
| JPN | 11010 | 5% | 0% | 160 | -2% |
| KOR | 8195 | 4% | 0% | -992 | 11% |
| LAC | 1694 | 1% | 5% | 228 | -3% |
| MEX | 4392 | 2% | 0% | -87 | 1% |
| MIN | 5468 | 3% | 4% | 203 | -2% |
| OAS | 11633 | 6% | 0% | -261 | 3% |
| ROW | 276 | 0% | 4% | 33 | 0% |
| RUS | 716 | 0% | 3% | 36 | 0% |
| SEA | 33572 | 16% | 0% | -1121 | 13% |
| SSL | 274 | 0% | 8% | 17 | 0% |
| SSO | 380 | 0% | 9% | 77 | -1% |
| TUR | 973 | 0% | 1% | 34 | 0% |
| USA | 35145 | 17% | 0% | -665 | 8% |
| ZAF | 686 | 0% | 2% | 9 | 0% |
| Total | 210819 | 100% | | -8823 | 100% |

Note: The table displays the exports by destination, the share of exports by destination, the tariff reduction in the policy experiments, and the projected change in exports by destination, in value and as a share of the total change in exports.

Table A-7: The initial value of exports, simulated tariff reduction, and projected change in exports from China

| Region | Exports value | Exports share | Tariff reduction | Change exports value | Change exports share |
|---|---|---|---|---|---|
| ASL | 2972 | 1% | 6% | 97 | 0% |
| AUS | 12023 | 2% | 3% | 821 | 2% |
| BRA | 7252 | 2% | 12% | 2407 | 7% |
| CAN | 16947 | 4% | 1% | 1035 | 3% |
| CHN | 0 | 0% | 0% | 0 | 0% |
| E27 | 92011 | 19% | 2% | 10396 | 30% |
| EFT | 4469 | 1% | 0% | -8 | 0% |
| GBR | 13908 | 3% | 2% | 1255 | 4% |
| IDN | 7743 | 2% | 0% | -512 | -1% |
| IND | 16966 | 4% | 6% | 2685 | 8% |
| JPN | 38827 | 8% | 0% | 161 | 0% |
| KOR | 34968 | 7% | 3% | 3957 | 11% |
| LAC | 19937 | 4% | 5% | 2437 | 7% |
| MEX | 24952 | 5% | 1% | 1404 | 4% |
| MIN | 24915 | 5% | 6% | 4010 | 12% |
| OAS | 30482 | 6% | 0% | -1016 | -3% |
| ROW | 4543 | 1% | 4% | 573 | 2% |
| RUS | 7468 | 2% | 4% | 884 | 3% |
| SEA | 55377 | 11% | 1% | -607 | -2% |
| SSL | 3248 | 1% | 9% | 484 | 1% |
| SSO | 2403 | 0% | 10% | 619 | 2% |
| TUR | 7972 | 2% | 0% | -140 | 0% |
| USA | 49753 | 10% | 1% | 3118 | 9% |
| ZAF | 3166 | 1% | 4% | 453 | 1% |
| Total | 482304 | 100% | | 34514 | 100% |

Note: The table displays the exports by destination, the share of exports by destination, the tariff reduction in the policy experiments, and the projected change in exports by destination, in value and as a share of the total change in exports.

Table A-8: The initial value of imports, simulated tariff reduction, and projected change in imports to China

| Region | Imports value | Imports share | Tariff reduction | Change imports value | Change imports share |
|---|---|---|---|---|---|
| ASL | 232 | 0% | 0% | -18 | 0% |
| AUS | 1874 | 1% | 4% | 314 | 1% |
| BRA | 1277 | 0% | 7% | 635 | 2% |
| CAN | 2226 | 1% | 3% | 253 | 1% |
| CHN | 0 | 0% | 0% | 0 | 0% |
| E27 | 36934 | 12% | 5% | 9733 | 35% |
| EFT | 3667 | 1% | 4% | 750 | 3% |
| GBR | 2145 | 1% | 4% | 556 | 2% |
| IDN | 1455 | 0% | 0% | -165 | -1% |
| IND | 1504 | 0% | 5% | 464 | 2% |
| JPN | 62052 | 20% | 4% | 11776 | 42% |
| KOR | 79089 | 26% | 3% | 10293 | 37% |
| LAC | 1645 | 1% | 0% | -178 | -1% |
| MEX | 1160 | 0% | 3% | 125 | 0% |
| MIN | 2955 | 1% | 1% | -68 | 0% |
| OAS | 43117 | 14% | 1% | -2747 | -10% |
| ROW | 689 | 0% | 5% | 189 | 1% |
| RUS | 789 | 0% | 4% | 162 | 1% |
| SEA | 51719 | 17% | 0% | -5376 | -19% |
| SSL | 133 | 0% | 0% | -14 | 0% |
| SSO | 58 | 0% | 3% | 8 | 0% |
| TUR | 298 | 0% | 8% | 176 | 1% |
| USA | 9654 | 3% | 3% | 1003 | 4% |
| ZAF | 295 | 0% | 6% | 128 | 0% |
| Total | 304967 | 100% | | 27997 | 100% |

Note: The table displays the imports by source, the share of imports by source, the tariff reduction in the policy experiments, and the projected change in imports by source, in value and as a share of the total change in imports.

Table A-9: The initial value of imports, simulated tariff reduction, and projected change in imports to the EU

| Region | Imports value | Imports share | Tariff reduction | Change imports value | Change imports share |
|---|---|---|---|---|---|
| ASL | 177 | 0% | 0 | -9 | -5% |
| AUS | 518 | 0% | 0 | 54 | 29% |
| BRA | 1876 | 0% | 0 | 369 | 197% |
| CAN | 2364 | 0% | 0 | 266 | 142% |
| CHN | 92011 | 19% | 0 | 10396 | 5545% |
| E27 | 256941 | 52% | 0 | -13171 | -7025% |
| EFT | 14423 | 3% | 0 | -755 | -403% |
| GBR | 13611 | 3% | 0 | -702 | -375% |
| IDN | 1848 | 0% | 0 | -68 | -36% |
| IND | 3851 | 1% | 0 | 141 | 75% |
| JPN | 13423 | 3% | 0 | 1198 | 639% |
| KOR | 11001 | 2% | 0 | -607 | -324% |
| LAC | 1936 | 0% | 0 | -44 | -24% |
| MEX | 1640 | 0% | 0 | -71 | -38% |
| MIN | 6531 | 1% | 0 | 156 | 83% |
| OAS | 5743 | 1% | 0 | 238 | 127% |
| ROW | 5073 | 1% | 0 | -186 | -99% |
| RUS | 3271 | 1% | 0 | 206 | 110% |
| SEA | 23815 | 5% | 0 | 43 | 23% |
| SSL | 180 | 0% | 0 | -9 | -5% |
| SSO | 550 | 0% | 0 | -23 | -12% |
| TUR | 4203 | 1% | 0 | -236 | -126% |
| USA | 23713 | 5% | 0 | 3067 | 1636% |
| ZAF | 1638 | 0% | 0 | -65 | -35% |
| Total | 490337 | 100% | | 187 | 100% |

Note: The table displays the imports by source, the share of imports by source, the tariff reduction in the policy experiments, and the projected change in imports by source, in value and as a share of the total change in imports.