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Yadira Mori-Clement, Stefan Nabernegg and Birgit Bednar-Friedl

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Department of Economics
Department of Public Economics
University of Graz

Can preferential trade agreements enhance renewable electricity generation in emerging economies? A model-based policy analysis for Brazil and the European Union

Yadira Mori-Clement[1,2,*] Stefan Nabernegg[1,2] and Birgit Bednar-Friedl[2,3]

[1]*DK Climate Change, University of Graz, Austria*
[2]*Wegener Center for Climate and Global Change, University of Graz, Austria*
[3]*Institute of Economics, University of Graz, Austria*
**corresponding author, email: yadira.mori-clement@uni-graz.at*

Abstract

Preferential trade agreements with climate-related provisions have been suggested as alternative to a New Market Mechanism due to its potential not only to achieve Nationally Determined Contributions (NDCs) in emerging economies but also to lead to more ambitious targets in the first UNFCCC global stocktake in 2023. The objective of this research is therefore to analyze the effectiveness and quantify the economic impacts of such a trade agreement between Brazil and the European Union that aims to support renewable electricity generation. Using a multi-regional computable general equilibrium model, we find that the environmental effectiveness of a preferential trade agreement targeting renewable electricity generation strongly depends on its design. In particular, preferential trade agreements require additional elements to effectively contribute to mitigation as the sole removal of import tariffs on renewable energy technology is quite ineffective in scaling up the share of wind, solar, and biomass in Brazil. In contrast, a preferential trade agreement triggering FDI flows towards renewable electricity generation is effective in increasing the share of renewables in the generation mix and in reducing CO_2 emissions, while positively affecting the Brazilian economic performance. Finally, we compare the two previous approaches to a domestic energy policy: a combination of higher fossil fuel taxes and subsidies to renewable electricity generation. We find that although this domestic energy policy is more effective in mitigation terms than the FDI policy, economic performance is negatively affected in several sectors. When such economic costs are socially not acceptable, as it is likely in many emerging economies, properly designed preferential trade agreements could therefore be a suitable instrument for supporting the achievement of NDCs, and potentially increase their stringency for the next stock taking period.

Keywords: Preferential Trade Agreements with climate-related provisions, Environmental Goods, Renewable Energy, FDI, Emerging Economies, Brazil, European Union

1. Introduction

Although the Paris Agreement (2015) represents a significant step in global climate negotiations, the implementation of the current Nationally Determined Contributions (NDCs) may not be sufficient to achieve the 2°C target (Boyd et al. 2015; Rogelj et al. 2016; Schleussner et al. 2016). Estimations show that although these voluntary contributions may lower greenhouse gas (GHG) emissions, these reductions may lead to achieving a median warming of 2.6-3.1°C by 2100 (Rogelj et al. 2016). Thus, additional measures and actions have to be taken by all countries in order to keep global warming below the 2°C target. Since Durban (2011), the need for new market-based mechanisms (NMM) has been discussed, which go beyond mere offsetting and can achieve net emission reductions through scaling up mitigation actions in broad segments[1] of developing countries' economies (UNFCCC 2012)[2].

Although Article 6 of the Paris Agreement establishes and encourages voluntary cooperation among parties to achieve their NDCs through a *mechanism* (Article 4.4), no other specifications regarding its characteristics and nature are mentioned in the Accord[3]. As an alternative to the NMM, some scholars have therefore proposed preferential trade agreements (PTAs) with climate-related provisions (Dong and Whalley 2010, 2011; Leal-Arcas 2013, 2015; Brandi 2017; Morin and Jinnah 2018). Bilateral arrangements may enhance not only accessibility but also dissemination of goods that could contribute to achieving mitigation objectives through the removal of import and non-tariff barriers (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017). Trade liberalization of environmental goods[4] has the potential to decrease pollution abatement costs, thus generating incentives to adopt cleaner technologies in the importing country, while boosting markets of these goods in the exporting country.

In the context of the Paris Agreement, trade elements have been incorporated in the NDCs to deal with climate contributions. Although almost all NDCs include references that can be related to trade, nearly 45% made it directly, but only 22% included trade-specific measures (Brandi 2017)[5]. Most common trade-related references include targeting the renewable energy sector (100%), focusing on technology transfer (63%) and using international market mechanisms (56%). To a much less extent, tools such as trade regulations on climate grounds[6] (11%) and the removal of trade barriers (6%) were included. Regarding trade barriers, concrete measures were included such as the reduction of import

[1] What broad segments means, has to be defined by Parties and it may encompass sectoral and/or project-specific basis (UNFCCC 2013).

[2] In the literature, diverse options for NMM have been discussed (Sterk and Mersmann 2012; Gao et al. 2016): 1) project-based or also known as enhanced CDM or CDM plus (Brazil 2014), 2) NAMA crediting , 3) sectoral market mechanisms (Baron et al. 2009; Schneider and Cames 2009; Dransfeld et al. 2011; Schneider et al. 2014), and 4) bilateral crediting systems (Warnecke et al. 2015). All these proposals for NMM are not free of challenges and barriers .

[3] This *mechanism*, which also shares the twofold objective of the old CDM, is also informally called in the literature as the Sustainable Development Mechanism (SDM) (Marcu 2016).

[4] Although there is no a common-agreed definition of "environmental goods" (and services) due to complexities in defining this sector (Vossenaar 2016), it could encompass those goods (and services) used "*to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related waste, noise and eco-systems*" (UNSTATS/OECD 1999, p.9). Therefore, it may include all those goods (and services) related to clean-technologies, energy efficiency, pollution control, among others (Bucher et al. 2014). In addition to that, it might include low carbon products for final consumption as well as inputs to produce (and consume) low-carbon products (Dong and Whalley 2010).

[5] Brandi (2017) identified eleven trade-related elements, which are classified as follows: reducing trade barriers, regulating trade on climate grounds, regulating timber trade, standards and labelling, border carbon adjustments, renewable energy, fossil fuel subsidy reform, international market mechanisms technology transfer and response measures (Brandi 2017).

[6] This trade element has been included as NDC by Antigua and Barbuda, Bahamas, Republic of Congo, Cook Island, Djibouti, Eritrea, Gabon, Haiti, Kuwait, Mauritania, Namibia, Nigeria, Saint Lucia, Samoa, South Sudan, Togo, Tuvalu and Venezuela.

duties on renewable energy equipment[7] or tariff reductions in specific vehicles such as electric cars[8]. These measures have been proposed by several small countries[9]. Other trade instruments, such as the adoption of Border Carbon Adjustments, were explicitly considered by only one Party (i.e., Mexico).

In the present paper, we therefore analyze the potential and the effectiveness of preferential trade agreements with climate-related provisions for Brazil, an emerging economy with steadily rising CO_2 emissions over the last decades and NDCs that are according to the Climate Action Tracker insufficient with keeping global warming below the 2°C target (Climate Action Tracker 2018). Still, the marginal abatement costs (as percentage of GDP) of implementing the NDCs are highest for Brazil within the 10 most emitting countries (Hof et al. 2017) In its NDCs, Brazil targets the renewable energy sector as priority sector for mitigation, with a domestic target of increasing the share of renewables in the generation energy mix to 45% by 2030 through the expansion of solar, wind, biomass and hydro[10]. Although Brazil's NDCs are not dependent on international support, additional actions would require large-scale increase of international involvement through investment flows as well as technology transfer and diffusion, so the country "welcomes support from developed countries with a view to generate global benefits" (Brazil 2016, p.3).

In the case of top emitters such as the EU, although its NDCs do not explicitly refer to trade-related measures, the EU has been actively involved in incorporating climate-related provisions in its PTAs with emerging and developing economies in the last decades (Morin and Jinnah 2018). Some examples of climate-related provisions adopted are the removal of trade and non-trade barriers on climate goods and services relevant to mitigation (EU-Colombia and Peru 2012; EU-Korea 2010; EU-Georgia 2014), cooperation in the renewable energy sector (EU-Mexico 1997; EU-CARIFORUM 2008; EU-Central America 2012; EU-Georgia 2014; EU-Singapore 2014); promotion of foreign direct investment (FDI) in environmental technologies and services (EU-Korea 2010; EU-Central America 2012) or strengthening carbon market mechanisms (EU-Central America 2012)[11].

The objective of this research is therefore to analyze and quantify the impacts of a bilateral preferential trade agreement with climate-related provisions between Brazil and the EU. In particular, we look into two elements of such provisions: (i) removal of import tariffs on renewable energy equipment; and (ii) promotion of climate-related foreign direct investments. To put these policies into perspective, we compare them to a domestic renewable energy policy. This paper is structured as follows: section 2 reviews the literature on trade and climate with a focus on preferential trade agreements; section 3 provides some background information on current mitigation policies in Brazil. The methodological approach as well as selected scenarios are outlined in section 4, while section 5 displays results. Policy implications and conclusions are drawn in section 6.

[7] This specific trade measure has been proposed by Guyana and Lao.
[8] This specific trade measure has been proposed by Bahamas, Saint Lucia, and Saint Vincent and the Grenadines.
[9] By the moment, the reduction or removal of trade barriers in their NDCs has been included by Bahamas, Cuba, Djibouti, Guyana, Lao PDR, Niue, Saint Lucia, Saint Vincent and the Grenadines, Seychelles and Togo.
[10] Other measures explicitly included as part of the NDCs are the increase of sustainable biofuels in energy mix to 18%, strengthening policies targeting land use and forests, the promotion of new standards in clean technology and low carbon infrastructure in the industry sector as well as improvements in infrastructure in urban areas in the transportation sector. In addition, Brazil reserves the right for the possibility to use international market mechanisms.
[11] At very less extent, other climate-related provisions are the ratification and implementation of Kyoto Protocol (EU-Montenegro 2007), cooperation on adaptation to climate change (EU-Moldova 2014) and an agreement to address fossil fuel subsidies (EU-Singapore 2014).

2. Literature review

2.1. Impacts of trade liberalization on emissions

Trade liberalization may affect the environment through three main channels (Grossman and Krueger 1991); Copeland and Taylor 2004). The first channel is the scale effect or expansion of economic activity due to trade, which leads to an increase in energy use and thus in emissions. The second channel is the composition effect, which explains how trade liberalization may alter the domestic production structure; the direction of this effect depends on country's comparative advantages in emission-intensive sectors as well as on whether these sectors are expanding (or contracting). Finally, the technique effect explains how trade may contribute to reduce emissions by improving the way of producing (and consuming) goods through enhanced availability of low-carbon goods and technologies.

Via the technique effect, trade liberalization may create new opportunities for emerging markets such as those on low-carbon or environmental goods and cleaner technologies through two mechanisms (Grossman and Krueger 1993). First, a tariff removal on these goods will reduce the costs of cleaner technologies, contributing to its disseminating and transfer; second, trade may also increase income levels and thus the demand for low-carbon goods. Moreover, trade liberalization may also generate incentives to producers to increase their production on low-carbon goods and thus export them (Claro and Lucas 2007).

Empirical studies on trade openness and their effects on carbon dioxide emissions have been inconclusive (Cole and Elliot 2003; Managi 2004; Frankel and Rose 2005; Managi et al. 2008; Hubbard 2014; Ertugrul et al. 2016). Although some studies estimated increasing emissions due to the prevalence of scale effects (Cole and Elliot 2003; Frankel and Rose 2005; Managi 2004), other studies have found differences across group of countries, e.g., OECD versus non-OECD (Managi et al. 2008).

Due to the increasing recognition of the potential of trade to contribute to sustainable development goals, the Doha declaration (2001) called for the reduction or elimination of tariff and non-tariff barriers to environmental goods and services (EGS)[12] to improve their access. However, difficulties in outlining an approach to a multilateral reduction due to diverse interests as well as diverging positions on the benefits from trading these goods have prevented progress on this matter (Balineau and de Melo 2013; Sauvage and Timiliotis 2017). Well before Doha, the OECD[13] and the APEC[14] started working on elaborating their respective lists of environmental goods. Although these lists were designed with different purposes[15], both have contributed to frame WTO negotiations on this particular topic (Steenblick 2005; Sugathan 2013).

[12] Products considered under this classification targeted air pollution control, renewable energy, waste management as well as water and wastewater treatment (WTO 2018).

[13] The OECD list includes 164 goods and it encompasses clean technologies, products and services to decrease environmental risk and pollution as well as resource use (Bucher et al. 2014).

[14] The APEC list consists of 54 product subheadings used in solving, limiting or preventing environmental problems (Bucher et al. 2014). This list may include parts and components to generate electricity from renewable energy sources, equipment for filtering/purifying water, among other products (Vossenaar 2016).

[15] The purpose of the OECD list was to enhance the understanding of the dimensions of the environment industry, while APEC list was designed to facilitate negotiations on this matter (Steenblick 2005).

2.2. Preferential Trade Agreements with climate-related provisions

A bilateral or multilateral arrangement in the form of a PTA is a reciprocal trade agreement which grant preferential access to each other's markets favoring members through the reduction of tariff barriers and less stringent non-tariff barriers (Leal-Arcas 2015). In the last two decades, the incorporation of environmental provisions in these agreements has been rising, not only in number but also in scope and level of stringency (Jinnah and Morgera 2013); this rise offers room for innovative climate-supportive trade rules to deal with mitigation targets (Holzer and Cottier 2015; Brandi 2017).

PTAs hold a high potential to contribute to climate mitigation as they exhibit attributes of trade negotiations that could shape them as strong instruments (OECD 2007; Gehring et al. 2013; Morin and Jinnah 2018). First, the reduced number of participants may accelerate the bargaining processes; second, the direct reciprocity allows introducing sanctions and thus enhancing compliance. Third, PTAs also allow flexibility for policy experimenting with the possibility of yearly re-negotiations. Finally, they can directly contribute to address trade-related mitigation issues. Easing access and diffusion of environmental goods, services and technologies achieved through PTAs, may contribute to climate change mitigation objectives (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017).

The basic form of a PTA with environmental/climate-related provisions would include a removal of trade barriers (e.g., import tariffs) on low-carbon and environmental goods. Other climate-related provisions that may be incorporated into the negotiation of a PTA are the harmonization of low-carbon standards, removal of fossil fuels subsidies, the promotion of climate-related investments (e.g.: in renewable energy technologies) and technology transfers and other forms of cooperation such as FDI inflows (Holzier and Cottier 2015; van Asselt 2017; Brandi 2017).

PTAs may promote FDI (Büthe and Milner 2008; Medvedev 2011), which in turn could also contribute to mitigation targets through the transfer and dissemination of cleaner technologies (Corfee-Morlot et al. 2009; UNCTAD 2010; Buchner et al. 2011). Moreover, FDI has also a high potential to deliver positive effects for the environment through technology leapfrogging and spill-overs to domestic firms though the dissemination of good practices (Gallagher and Zarsky 2007). Empirical literature on FDI and its impacts on mitigation is still limited. Most studies test the pollution haven and the halo effect hypotheses [16] (Zhu et al. 2016). Available findings are inconclusive; some research supports reductions in emissions (Merican et al. 2007; Zhu et al. 2016; Shao 2017), while other studies do identify increase in emissions (Merican et al. 2007, Jorgenson 2007; Acharyya 2009; Behera and Dash 2017) or no effects (Perkins and Neumeyer 2009).

Currently, 85% of the PTAs contain at least one environmental provision[17] (DIE 2017), of which 14% address climate-specific issues. Most of these climate-related provisions focus on promotion of renewable energy and/or energy efficiency [18] and very few provide sanctions in case of non-compliance (Morin and Jinnah 2018). In general, most environmental provisions are not trade-related, thus they are treated as a separated issue from the trade agreement (Morin and Jinnah 2018). Some

[16] The pollution haven hypothesis (Chichilnisky 1994) tests whether FDI flows to host countries with less stringent environmental standards, while the pollution halo effect hypothesis (Dean 1992) tests whether FDI leads to positive externalities to the environment through the spread of clean technology and climate-friendly practices.

[17] Beside climate-related provisions, most environmental provisions address issues on biodiversity, waste and water management, fisheries, forests, deserts and ozone (Morin and Jinnah 2018). Biodiversity is by far the issue-area with most replication in several PTAs.

[18] Morin and Jinnah (2018) identified eight types of climate-related provisions in PTAs. In addition to the promotion of renewable energy and energy efficiency technologies, other provisions that directly address climate change have focused on cooperation on climate governance, reduction of GHG emissions, adaptation to climate change, ratification or implementation of climate agreements (e.g., Kyoto, UNFCCC) and harmonization of climate regulations.

reasons behind are, for instance, the potential high costs as a result of more stringent mitigation measures as well as political feasibility (Anuradha 2011; Leal-Arcas 2013).

Regarding evaluations of PTAs, there are few assessments available. Literature can be divided into quantitative and qualitative research. Most studies have focused on the NAAEC [19] or the environmental side agreement of the NAFTA. Regarding quantitative studies, one of the first assessments of the NAFTA was conducted by Grossman and Krueger (1991). Using a CGE model, they analyzed the compositional effect of the NAFTA on pollution (sulphur dioxide) in Mexico; results showed that there was no evidence of environmental degradation. In contrast, other studies show opposing results. Gallagher (2004) argued that environmental conditions worsened in Mexico, leading to an increase in sulphur and carbon dioxide emissions. This study also discusses the shortcomings of the NAAEC to deal with environmental issues. Similarly, using econometric techniques, Yu et al. (2011) also found a significant increase in emissions not only in Mexico but also in the US after 1994. Dong and Whalley (2011) used a multi-region general equilibrium model[20] to evaluate the impact of a tariff reduction on low-carbon intensive goods. They find that tariff reductions have a positive but quantitatively small impact on emission reductions and explain this effect by economic growth, which fuels emissions more than trade and its composition. Regarding qualitative studies, some have reported the acceleration of environmental reforms in some countries that negotiated PTAs with environmental provisions; that is the case of Singapore (FTA US-Singapore 2003); Chile (FTA US-Chile 2003) or Morocco (FTA US-Morocco 2004) (OECD 2007).

3. Current policies in Brazil to support renewable electricity generation in the context of the NDCs

According to the Brazilian NDCs, it is intended to reduce GHG emissions by 37% below 2005 levels in 2025 and by 43% in 2030. The renewable energy sector is priority for mitigation with a domestic target of increasing the share of renewables in the energy mix to 45% by 2030, which includes expanding the use of renewable sources (other than hydro) in the total energy share between 28% and 33% by 2030, and increasing the share of renewable (other than hydro) in the power supply to at least 23% by 2030 (Brazil 2016).

The Brazilian electricity sector is the largest in South America. Renewable energy sources account for almost 80% of total electricity generation and hydropower represents 65%, while biomass 9.4%, wind 6.7% and solar 0.02% (EPE 2017b). As the energy mix strongly relies on hydropower, this makes Brazil vulnerable to power supply shortages in drought years as it was the case in 2001, 2012 and 2015 (Krishnaswamy and Stuggins 2007; Schmidt et al. 2016). Therefore, energy mix diversification should be considered as backbone strategy to enhance energy security and decrease reliance on fossil fuels (da Silva et al. 2016). Although the share of other renewable energy sources such as wind and solar are still low in the energy mix (6.7% and 0.02%, respectively), its potential is

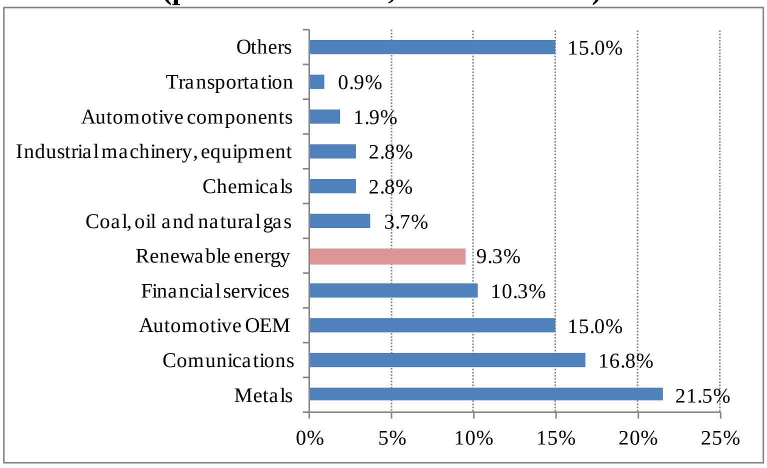
[19] The North American Agreement on Environmental Cooperation (NAAEC) is an environmental agreement between the US, Canada and Mexico. It came into effect in 1994. The NAAEC contains a declaration of principles and objectives regarding conservation and environment protection.
[20] This model covers trade for US, EU, China and the rest of the world. The high-emission sector is represented by the manufacturing sector, while the low-emission sector includes service and agriculture.

very large[21] (CRESESB 2001; Bueno et al. 2006); this makes Brazil an attractive market for investments in renewable energy technologies.

Regarding incentives for investments in the renewable energy sector, the Program of Incentives for Alternative Electricity Sources (PROINFA) launched in 2002 has played a role in promoting wind, biomass and small hydropower plants in Brazil. Nearly 95% of projects have been financed by this program by 2011 (Pereira et al. 2012). Although solar was excluded from PROINFA, the government considered it as beneficiary of short-term fiscal incentives in the form of tax exemptions and import tax reductions[22] through the Special Taxation Regime of Incentives for the Development and Production of Alternative Energy Source (REINFA). However, promotion of solar energy is still weak (Ferreira et al. 2018). In addition, there are still obstacles to promote technologies other than hydro such as high transmission and integration costs (Schmidt and Guedes-Ribeiro 2018).

With respect to fossil fuels, oil and natural gas are subject to several taxes at the federal, state and municipal level (OECD 2014). Some examples are the CIDE fuel consumption tax (for imports and retail sales) and social security contributions such as the PIS (Program of Social Integration) and the COFINS (Social security financing contribution). However, producers may also enjoy tax exemptions under several incentive regimes[23] to promote investments in the sector (OECD 2014; Nuamy-Barker 2015). In addition, oil producers are exempted from the payment of corporate income taxation: the corporate income tax (IRPJ) and the social contribution tax on profits (CSLL) according to the new tax regime law established in 2017 (INESC 2018).

Figure 1: Share of sectoral greenfield investment by the EU in Brazil (period 2006-2015, in EUR million)



Source: APEX-BRASIL (FDI Markets 2016).

[21] The Brazilian North-East is the region with the strongest wind potential during the dry or winter season, which coincides with the season of lower rainfall intensity in the year (CRESBS 2001). Moreover, solar potential is greater in summer, period of the year when energy demand increases (Jong et al. 2013). These seasonal complementarities offer a great opportunity to diversify energy sources as well as represent a challenge how to integrate renewable and intermittent energy sources into the electricity sector (Oliveira et al. 2017).

[22] This includes exemptions of the state value-added tax (ICMS) and social integration/social security contribution taxes (PIS/COFINS) on net electricity as well as import tariff reductions from 14% to 2% on capital goods and related components.

[23] Some examples are the Special Incentive Regime for Infrastructure Development (REIDI) which exempt companies from paying social security contributions such as the PIS and the COFINS on goods for infrastructure projects, the Special Tax Regime for Goods used in the Exploration (REPETRO) which exempt companies from the PIS, the COFINS and the IPI (Excise duty on industrialized products) when importing goods by sea for research activities and extraction or the (REPORTO) which exempt companies from the PIS; the COFINS and the IPI when investing in port infrastructure.

In terms of trade, the EU is Brazil's second largest trading partner accounting for almost 20% of its total trade in 2016[24] (EuroStat 2017). Its trade with the EU accounts for 30.8% of the EU's total trade with Latin America. This relevance is not only reflected in trade but also in FDI considering that Brazil is the third EU's main FDI inflow destination worldwide (APEX-BRASIL 2017). At the sectoral level (Figure 1), the estimated announced productive FDI[25] in renewable energy by the EU in Brazil represents 9.3% of the total for period 2006-2015 (FDI Markets 2016).

4. Methodology

To investigate the macroeconomic effects of different PTA instruments we use a multi-regional multi-sectoral computable general equilibrium model. This kind of model is state of the art for investigating the effects of trade agreements and environmental policy and are widely applied in the literature (see e.g., Böhringer et al. 2015; Klepper and Peterson 2006). We consider this model especially suited for our analysis because of its representation of regional and sectoral details of the economy, as well as international trade linkages.

4.1. Model

The CGE model, based on Nabernegg et al. (2017) and Schinko et al. (2014), represents the structure of an economy by national and international trade flows organized by regions and sectors. In each region agents interact on the supply and demand side of different markets. Further technical specifications of the model can be found in the appendix.

Figure 2 shows the basic flows for one model region (r). The regional household is endowed with the primary factors of labor (L), capital (K), and natural resources (R). These primary factors are used in the domestic production process, that uses also intermediate inputs (ID_{ir}) from all other sectors (i). The primary factors are assumed to be perfectly mobile between the different sectors, but immobile between regions. Sectoral firms are assumed to produce under perfect competition and provide their produced output for exports (EX_{irs}) to other regions (s) or domestic supply. The different degree of substitutability between sectoral inputs is captured by nested constant elasticity of substitution (CES) functions for each sector. For the preferences between domestically produced and imported products we follow the Armington assumption (Armington, 1969), which treats sectoral products from different regions as imperfect substitutes. Sectoral imports (IM_{irs}) and domestic production are therefore grouped in an Armington aggregate (G_{ir}), which feeds into the domestic supply (D_{ir}). Finally, the domestic supply is demanded by other firms as intermediate inputs and as final demand (FD_{ir}) of the regional household. Households optimize their consumption level given their income from labor, capital, and natural resources. Final demand (by households and the government) is represented by nested CES functions in the model.

[24] EU imports from Brazil are dominated by primary products, (i.e., foodstuffs, beverages and tobacco products (18.2%), vegetable (17.9%) and mineral products (16.3%)), while EU exports are mainly on machinery and appliances (26.6%), chemical products (23.6%) and transport equipment (13.6%).
[25] According to FDI Markets, this data on announced productive FDI represents all greenfield investment projects or new productive investments made by existing companies

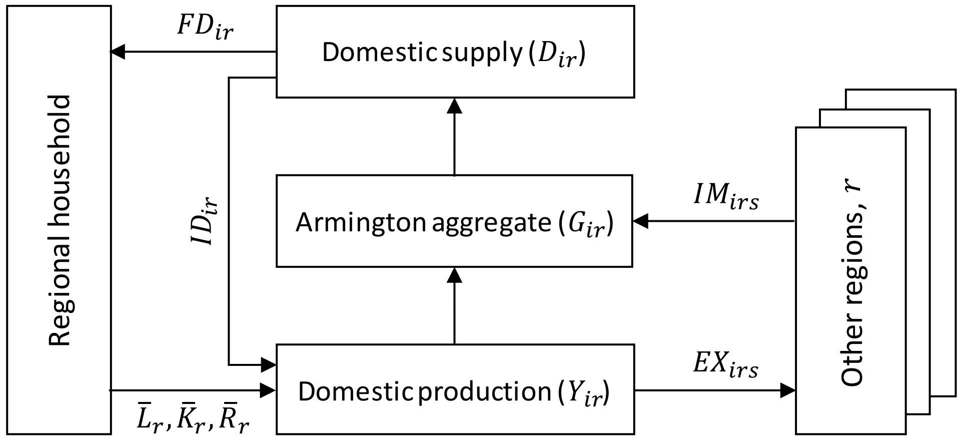


Figure 2: Economic representation in each region of the CGE model. FD_{ir} …Final demand, ID_{ir}…Intermediate demand, $\bar{L}_r$…Labor endowment, $\bar{K}_r$…Capital endowment, $\bar{R}_r$…Natural resource endowment, IM_{irs}…Imports, EX_{irs}…Exports

For the calibration of the model, we use economic data from the Global Trade Analysis Project (GTAP) Version 9 (Aguiar et al. 2016). The latest year of data, that we use as benchmark, is 2011. Substitution elasticities for sectoral production functions are specified from different studies from the literature (Aguiar et al. 2016; Beckman and Hertel, 2010; Okagawa and Ban, 2008). To reduce complexity and computational intensity, we aggregate the data provided by GTAP for 140 regions and 57 sectors to 10 regions and 25 economic sectors (see Appendix for aggregation list). Regions include Brazil, Europe and their most important trading regions (e.g., USA, China, Mercosur), as well as other main economic regions.

The electricity sector on the other hand is further disaggregated into different production technologies as well as transmission and distribution, to allow for an investigation of climate and energy related instruments. To differentiate across generation technologies, we use data on installed and generation capacity by technology from the Brazilian Energy Research Office (EPE 2017a, 2017b). Together with information on Levelised Cost of Electricity (LCOE) for each technology from Jong et al. (2015) and Silva et al. (2016) we can then calculate their monetary output values and assign the residuals to the sector of transmission and distribution. Note that these LCOEs estimates draws on case study data from 13 projects for several renewable energy technologies in Brazil. Fuel-specific inputs from the aggregated electricity sector are attributed to the corresponding disaggregated production technology of coal, oil, gas and nuclear power. We further use the investment costs provided in Jong et al. (2015) and Silva et al. (2016) to assign the corresponding capital inputs as share of total inputs for each technology. Other intermediate inputs are distributed proportionally to the output values of the technology and adapted manually to match input-output equality. Each of the disaggregated production technologies is implemented with fixed input shares (zero elasticities of substitution), while we allow for a high substitution between the technologies (see Appendix for further specifications).

Combustion emissions of CO_2 in the CGE model are depicted by sector-specific coefficients and linked with a zero elasticity of substitution to the use of fossil fuels. Additionally, we include industrial process emissions, emerging from chemical or physical processes in the production of steel, cement, and chemical products. Data on combustion emissions are included in the GTAP database and complemented with Eurostat data. Industrial process emission data comes from the UNFCCC database and CDIAC.

4.2. Policy scenarios

We base our scenario design in the context of the NDC of Brazil and compare the contributions of two aspects of climate related provisions in PTAs and a domestic energy policy to reduce carbon emissions by the expansion of renewable electricity generation.

The first policy scenario (*Preferential Trade Agreement*) is characterized by reductions in direct trade barriers for renewable electricity technologies, such as wind turbines or photovoltaic panels, between the EU and Brazil. In particular, we assume that import tariffs for such technology imports are removed which should increase the installation of renewable electricity capacities using European technology at reduced costs.

The second policy scenario (*Foreign Direct Investment*) considers that a preferential trade agreement includes the promotion of European FDI in renewable electricity generation in Brazil. While over the past decade renewable energy was already targeted by European FDI to some extend (see: Section 3), we consider such investment to increase substantially in this scenario. The distribution of investment between the different renewable electricity technologies is assumed to continue its latest pattern of high wind and solar shares. In this scenario, we set the level of European FDI that is consistent with the Brazilian NDC target for 2030 which demands a combined share of renewable electricity supply from wind, biomass, and solar of 23%.

In the third policy scenario (*Domestic Energy Policy*), we investigate a change in domestic energy taxes in Brazil. Here we assume that the relationship between fossil fuel and renewable electricity taxes is adjusted towards the relationship in Europe. While in Brazil fossil fuel use in industry and electricity production is currently much less taxed than electricity from renewable sources, in the EU there is a much smaller gap between these tax rates on fossil and renewable sources of energy (OECD 2018). The adapted tax regime for this scenario is set up as revenue neutral in which revenues from increased fossil fuel taxes finance subsidies for renewable electricity production.

The promotion of FDI in renewable electricity technologies (*Foreign Direct Investment* scenario) is implemented in the CGE model as additional European capital input in the renewable electricity sectors in Brazil. The FDI is calibrated to increase the share of renewable electricity other than hydro from currently 15% to 23%, fulfilling the NDC target for 2030. Additionally, we increase the capital effectiveness of FDI compared to the domestic capital input, reflecting lower European interest rates and continued technological progress, especially in solar technology. In the scenario of domestic policy in Brazil (*Domestic Energy Policy* scenario), we implement a revenue neutral combination of an increase in fossil fuel taxes and reduction of renewable electricity taxes. We exogenously increase the tax rates in the fossil fuel sectors of coal, crude oil, gas and refined oil and coal products to a level, which reflects the European relation of fossil fuel taxes to electricity taxes. The additionally generated tax revenue is used as subsidy to the renewable electricity sectors, with the subsidy rate determined endogenously in the model to guarantee revenue neutrality. This procedure results in a tax increase on fossil fuels, most relevant for refined oil and coal products, from 0.4% to 3.9% which is on a similar level as tax rates in this sector e.g., in other Latin American region or the US. The revenue recycling leads to an overall subsidy rate of 17% for the renewable electricity production.

5. Results

Figure 3 illustrates the electricity generation mix across generation technologies for the base year (2016) and the three policy scenarios. In the base year, 81.5% of electricity in Brazil is generated from renewables, with the largest contribution from hydro (66.6%), and comparatively smaller contributions from biomass (8.7%) and wind (6.2%) while the share of solar is negligible (0.01% of total generation mix). In two policy scenarios, the share of both wind and solar is increased: The *Foreign Direct Investment* scenario leads to an increase in wind (11% of total generation mix), biomass (11%), solar (3%), and also to a small increase in hydro (67.7%). This increase in the share of wind and solar is due to the fact that FDI flows are resource specific, where a relatively large share of investment in the last years was directed towards the 'new' renewables solar and wind. The *Domestic Energy Policy* scenario leads to a comparatively stronger increase in hydro (77.8% of total generation mix), followed by biomass (10.4%) and wind (7.5%) and no visible increase in solar. This change reflects that the support for renewables in this scenario is assumed to be similar for hydro, wind, biomass, and solar, without consideration of the different economic profitability of these technologies. Finally, the *Preferential Trade Agreement* scenario does not lead to a shift in the generation mix compared to the base year because the tariff reduction for low carbon technologies for inputs to the electricity sector leads only to marginal cost advantages that are insufficient to trigger additional investment into renewable electricity generation.

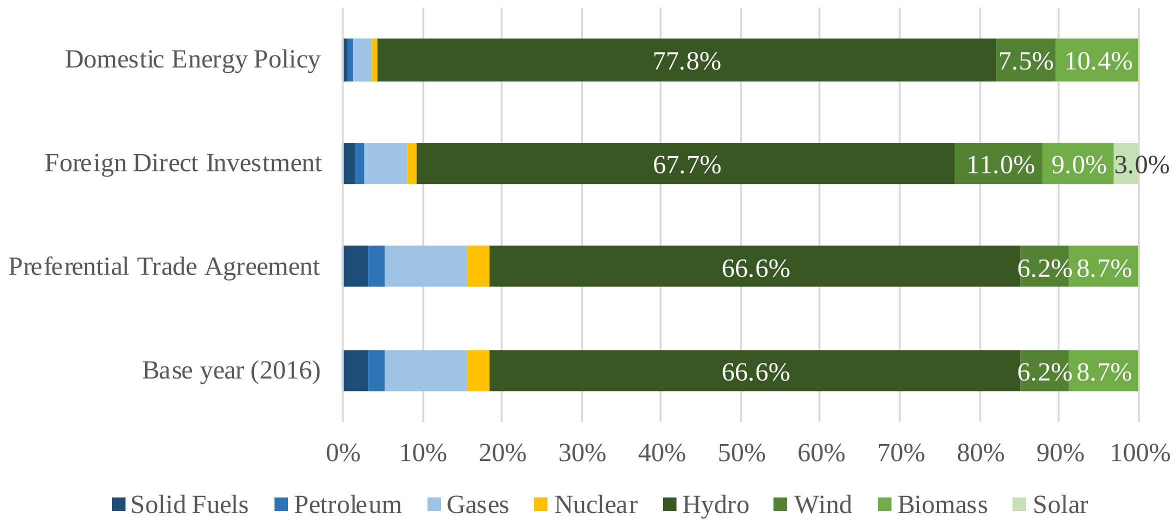


Figure 3: Electricity generation mix (share of average annual generation in kWh) in Brazil for the base year (EPE 2017a, 2017b), and the three policy scenarios

Since each of the policies is differently effective in increasing the shares of renewables in the electricity mix, the effects on GDP and CO_2 emissions are compared in relative terms, i.e., the effect is presented per 1% point increase in the share of the new renewables (wind, solar, and biomass) in the generation mix. Figure 4 therefore illustrates how the three policies affect GDP in Brazil, the European Union, and the Rest of the World. The *Foreign Direct Invstment* policy leads to a positive contribution to GDP in Brazil of 0.03% because European foreign investment generates economic activity in Brazil not just in the electricity sector but also in other sectors (agricultural crops, energy intensive industries such as iron and steel (I_S), chemicals (CRP); food products (MEG), metals (MET) and machinery (TEO)). Since this investment is no longer spent in Europe, European GDP is negatively affected, but this effect is negligible (-0.003%) because the European GDP is a manifold of the Brazilian GDP. The *Domestic Energy Policy* scenario leads to a reduction in Brazilian GDP by 0.02%, even though the policy costs of renewable electricity support are financed out of additional revenues from fossil fuel taxes and therefore the costs for the electricity sector are comparatively small. However, the higher fossil fuel taxes lead to higher costs in other energy intensive sectors and in final demand, dampening sectoral output (most strongly in fossil fuel sectors, to a smaller degree also in agriculture, transport, in energy intensive industries like chemicals; and in service sectors). Due to international trade linkages, both policies lead also to slight negative effects on the Rest of the World because Brazilian imports decrease slightly in both scenarios. Since also Brazilian exports decline in the *Domestic Energy Policy* scenario, the effect on GDP in the Rest of the World is stronger than in the *Foreign Direct Investment* scenario. Again, the size of the effect of the *Preferential Trade Agreement* policy on Brazilian GDP, and also in the two other policy regions, is negligible.

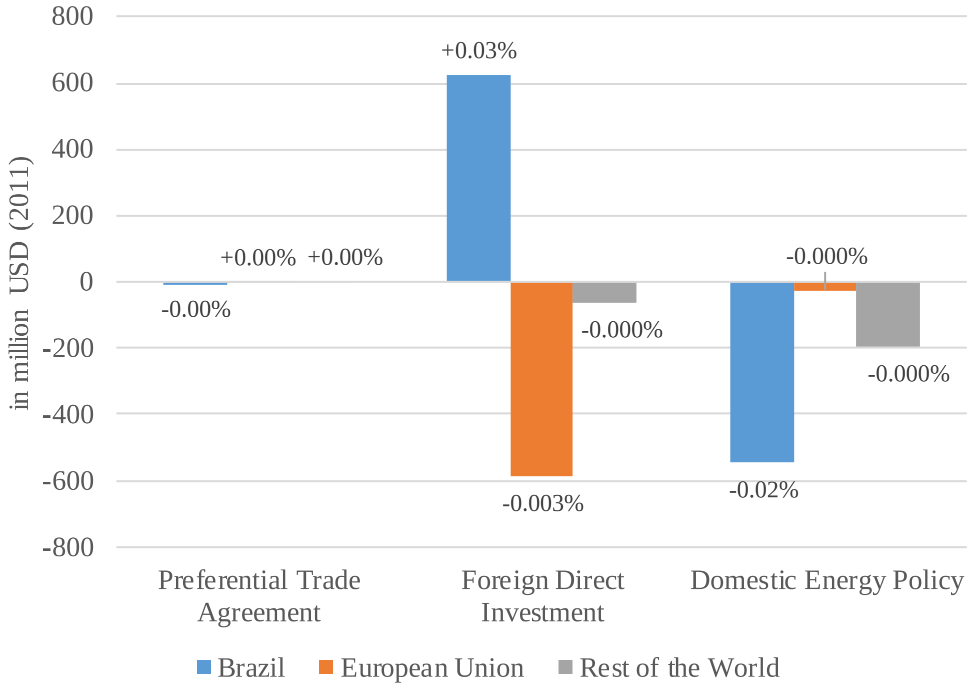


Figure 4: Normalized change in GDP (absolute change and % change, both relative to the base year) by policy region for the three policy scenarios.

Note: To make the effect size of the different policies comparable, GDP effects are normalized per 1%-point increase in the share of wind, solar, and biomass in the Brazilian electricity generation mix. Rest of the World is the aggregate of all other model regions except Brazil and EU.

Figure 5 illustrates how CO_2 emissions change in the three policy scenarios. The *Domestic Energy Policy* scenario is most effective in reducing emissions (by 1.86% per 1%-point increase in the share of wind, solar and biomass in the Brazilian generation mix), followed by the *Foreign Direct Investment* policy (decrease of 0.33% in CO_2 emissions per 1%-point increase in the share of wind, solar, and biomass). This is due to the fact that the *Foreign Direct Investment* policy affects emissions directly only in the electricity sector in Brazil; emissions in other industry and service sectors even increase slightly due to cheaper electricity. In contrast, the *Domestic Energy Policy* affects fossil fuel use also in all other sectors, leading to significant emission reductions in fossil fuel and transport sectors as well as by households. With this latter policy, the economy-wide reduction in CO_2

emissions is therefore contributed by 77% from the electricity sector and by 23% from all other sectors and households. None of the policies leads to emission increases in the European Union or in the Rest of the World; in the European Union, emissions are even marginally reduced by 0.004% (*Foreign Direct Investment* scenario) and by 0.003% (*Domestic Energy Policy* scenario) due to reduced economic activity (negative GDP effects in the European Union in both scenarios). The *Preferential Trade Agreement* policy has again no significant impact on CO_2 emissions as it is not effective in increasing the share of 'new' renewables in the Brazilian electricity generation mix.

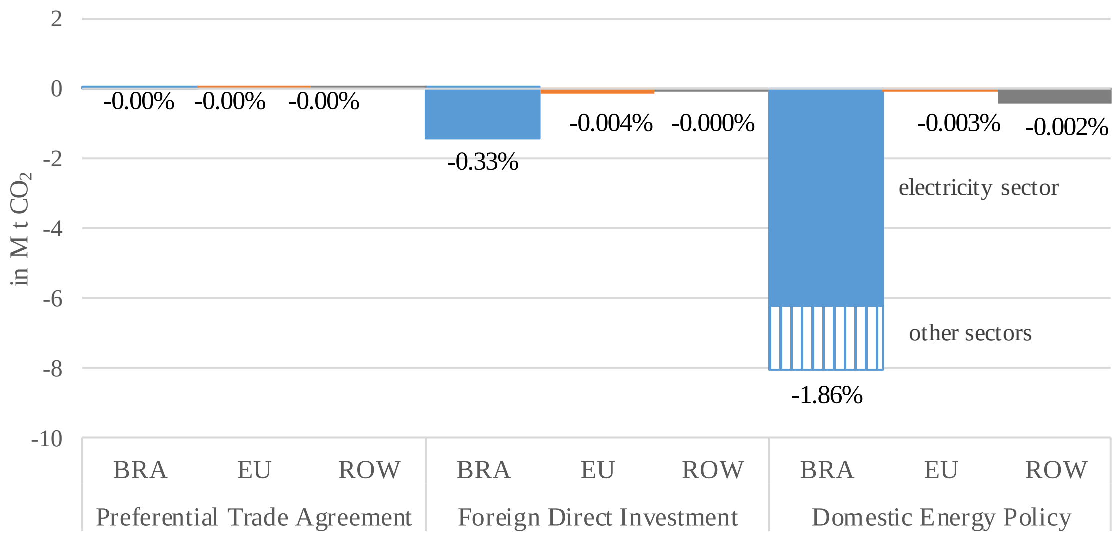


Figure 5: Normalized change in CO_2 emissions (absolute change and % change, both relative to the base year) by policy region for the three policy scenarios and decomposition of effect in Brazil into reduction within the electricity sector and in all other sectors and households.

Note: To make the effect size of the different policies comparable, GDP effects are normalized per 1%-point increase in the share of wind, solar, and biomass in the Brazilian electricity generation mix. Region abbreviations: BRA = Brazil, EU = European Union; ROW = Rest of the World (aggregate of all other model regions).

6. Discussion and conclusions

Preferential trade agreements with climate-related provisions have been suggested as alternative to New Market Mechanisms because they have potentially several advantages: the small number of parties increases the likelihood and speed of such an agreement; the possibility of even yearly negotiations provides much greater flexibility; and they can potentially not only make the achievement of NDCs in emerging economies more likely but may also lead to more ambitious targets in the upcoming UNFCCC global stocktake.

The present paper demonstrates, however, that preferential trade agreements need to have certain elements to effectively contribute to mitigation and lead to wider economic benefits. In line with Dong and Whalley (2011), we find that the removal of import tariffs on renewable energy technology (policy scenario *Preferential Trade* Agreement) is quite ineffective in scaling up the share of wind, solar, and biomass in Brazil. The reason for this result is twofold: first, the renewable energy technology is already today only subject to comparatively small tariff rates; and second, the cost contribution of these technologies to the unit costs in renewable electricity generation is comparatively small. Tariff reductions on renewable energy technology, as one type of environmental goods and services, are therefore not a sufficient measure to reinforce NDCs in emerging countries but need to be combined with other measures.

One potential complementary measure to the removal of trade barriers on environmental goods and technologies is the support of FDI. In our model-based policy analysis, we find that FDI by the European Union in Brazil with a focus on renewable electricity generation is effective in both increasing the share of wind, solar, and biomass in the Brazilian generation mix and in reducing CO_2 emissions. Moreover, the FDI policy has a positive impact on the Brazilian economic performance (measured as % change in GDP). We therefore conclude that when a PTA is able to trigger substantial FDI flows, then a PTA can be an effective instrument to mitigation in emerging economies. In order to attract this required level of FDI into the renewable energy sector, PTAs should therefore be complemented with other policy instruments. Domestic policies such as fiscal measures[26], i.e., tax incentives, have proved to be effective instruments to attract investments in new renewables (Marques and Fuinhas 2012; Polzin et al. 2015; Wall et al. 2018). Other fiscal instrument that has shown effectiveness is the feed-in tariff (Verbruggen and Lauber 2012; Bolkesjo et al. 2014; Wall et al. 2018).

As a final policy simulation, we compared the two PTA elements to a domestic energy policy. Here the assumption was that fossil fuel taxes are raised (to levels similar to the rates in the USA or other Latin American countries) and that these tax revenues were used to subsidize renewable electricity generation from wind, solar, and biomass. There are two striking differences to the FDI policy case: first, the domestic energy policy is more than five times effective in mitigation as is the FDI policy case; second, the effect of the domestic energy policy on the Brazilian GDP is negative, due to higher oil prices which affect output negatively not only in the fossil fuel sectors (and here primarily the oil sector) but also in energy-intensive industrial sectors. While the domestic energy policy is therefore highly effective in terms of mitigation, there is a trade-off in terms of higher energy prices and reduced economic performance.

When looking at emission reductions, our model-based policy analysis for Brazil and the EU demonstrates that domestic energy policies clearly exert a bigger leverage on emission reductions within emerging economies like Brazil than preferential trade agreements (capable of generating FDI and not just removing import tariffs on renewable energy technologies) can do by themselves. But as domestic energy policies may have negative economic consequences, preferential trade agreements capable of generating FDI can buffer this side-effect and thereby increase the political acceptability of ambitious NDC targets in the electricity sector. In turn, domestic energy and climate policies, such as support for renewables, can also attract FDI flows, and ensure that preferential trade agreements unfold their contribution to mitigation and economic performance. Ultimately, domestic policies and preferential trade agreements could form therefore an effective policy package that serves both needs of mitigation and economic performance.

[26] Wall et al. (2018) found that carbon pricing instruments are also effective in attracting renewable energy FDI. In particular, emission trading schemes showed more effectiveness in non-OECD countries, while carbon taxation in OECD countries.

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Appendix

We extend the model and scenario description of section 4 with further technical details in this appendix. Table A-1 and Table A-2 depict the regional and sectoral aggregates used in the model, aggregated from the regions and sectors provided in the GTAP database.

On a sectoral level, we further disaggregate the electricity sector for Brazil and Europe. In the model we nest the different electricity technologies with in one electricity sector (see Figure A-1). Each technology consists of capital, labor and sectoral intermediate inputs. Fossil fuel technologies further need technology specific fuel inputs causing CO_2 emissions from their combustion. We assume fixed input shares within each technology by assigning a zero elasticity of substitution for all electricity technologies. A substitution between the different technologies is, however, allowed by the elasticity top, for which we assign a value of 10. To supply a unit of electricity we further nest the transmission and distribution sector (consisting again of capital, labor and sectoral intermediate inputs) with a constant share to the electricity generation from the different technologies.

Figure A-1: Nesting structure of the disaggregated electricity sector

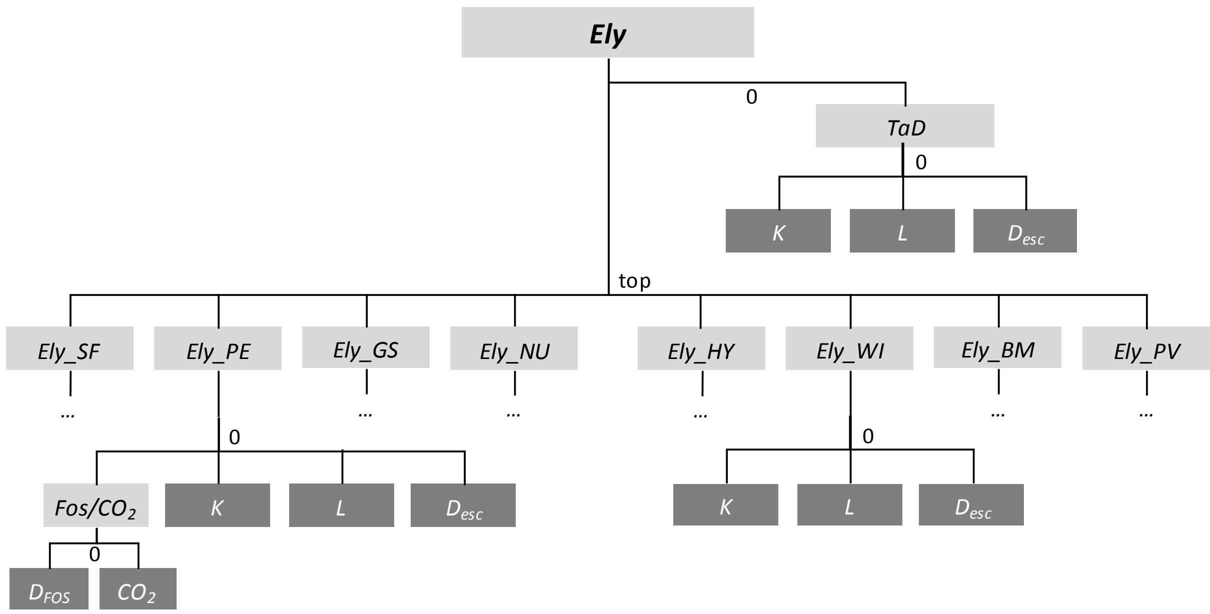


Table A-1: Sectoral aggregation in the CGE model from the GTAP database (Aguiar et al. 2016)

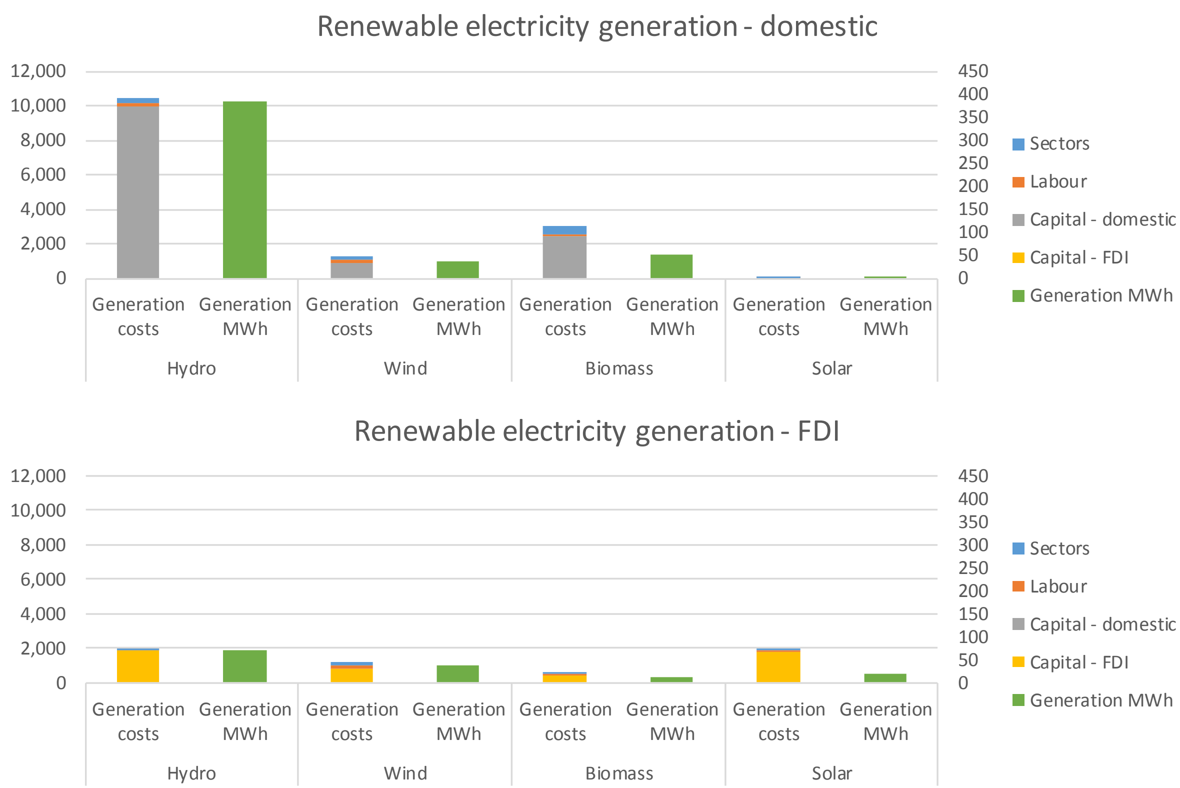
Model sectoral aggregate		Aggregated GTAP sectors (code and sector)					
AVEG	*Agricultural crops*	PDR	Paddy rice	WHT	Wheat	GRO	Cereal grains nec
		V_F	Vegetables, fruit, nuts	PFB	Plant-based fibers	OCR	Crops nec
OILS	*Oil seeds*	OSD	Oil seeds				
SUGA	*Sugar plants*	C_B	Sugar cane, sugar beet				
AMEA	*Agriculture, animalistic*	CTL	Bovine cattle, sheep and goats, horses	OAP	Animal products nec	RMK	Raw milk
		WOL	Wool, silk-worm cocoons				
EXT	*Extraction*	FRS	Forestry	FSH	Fishing	OMN	Minerals nec
COA	*Coal*	COA	Coal				
OIL	*Oil*	OIL	Oil				
GAS	*Gas*	GAS	Gas	GDT	Gas manufacture, distribution		
MEG	*Food products*	OMT	Meat products nec	CMT	Bovine meat products	VOL	Vegetable oils and fats
		MIL	Dairy products	PCR	Processed rice	SGR	Sugar
		OFD	Food products nec	B_T	Beverages and tobacco products		
TEX	*Textiles*	TEX	Textiles	WAP	Wearing apparel	LEA	Leather products
WOOP	*Wood and paper products*	LUM	Wood products	PPP	Paper products, publishing		
P_C	*Petroleum, coal products*	P_C	Petroleum, coal products				
CRP	*Chemicals*	CRP	Chemical, rubber, plastic products				
NMM	*Mineral products*	NMM	Mineral products nec				
I_S	*Iron and steel*	I_S	Ferrous metals				
MET	*Metals*	NFM	Metals nec	FMP	Metal products		
MVE	*Motor vehicles and parts*	MVH	Motor vehicles and parts	OTN	Transport equipment nec		
TEO	*Machinery*	OME	Machinery and equipment nec				
TEC	*Electronic equipment*	ELE	Electronic equipment	OMF	Manufactures nec		
ELY	*Electricity*	ELY	Electricity				
ELY_SF	*Solid Fuels*						
ELY_PE	*Petroleum*						
ELY_GS	*Gases*						
ELY_NU	*Nuclear*						
ELY_HY	*Hydro*						
ELY_WI	*Wind*						
ELY_BM	*Biomass*						
ELY_PV	*Solar*						
TaD	*Transmission and distribution*						
CNS	*Construction*	CNS	Construction				
TRD	*Trade*	TRD	Trade				
SERV	*Services*	CMN	Communication	OFI	Financial services nec	ISR	Insurance
		OBS	Business services nec	ROS	Recreational and other services	DWE	Dwellings
OSG	*Government services*	OSG	Public Administration, Defense, Education, Health	WTR	Water		
TRN	*Transport*	WTP	Water transport	OTP	Transport nec	ATP	Air transport

Table A-2: Regional aggregation in the CGE model from the GTAP database (Aguiar et al. 2016)

Model regional aggregate		Aggregated GTAP regions (code and region)					
BRA	*Brazil*	BRA	Brazil				
EUN	*European Union*	AUT	Austria	BEL	Belgium	CYP	Cyprus
		CZE	Czech Republic	DNK	Denmark	EST	Estonia
		FIN	Finland	FRA	France	DEU	Germany
		GRC	Greece	HUN	Hungary	IRL	Ireland
		ITA	Italy	LVA	Latvia	LTU	Lithuania
		LUX	Luxembourg	MLT	Malta	NLD	Netherlands
		POL	Poland	PRT	Portugal	SVK	Slovakia
		SVN	Slovenia	ESP	Spain	SWE	Sweden
		GBR	United Kingdom	CHE	Switzerland	NOR	Norway
		XEF	Rest of EFTA	BGR	Bulgaria	HRV	Croatia
		ROU	Romania				
USA	*United States of America*	USA	United States of America				
CHN	*China*	CHN	China				
MER	*Mercosur*	ARG	Argentina	PRY	Paraguay	URY	Uruguay
ROW	*Rest of the World*	CAN	Canada	XNA	Rest of North America	ALB	Albania
		BLR	Belarus	RUS	Russian Federation	UKR	Ukraine
		XEE	Rest of Eastern Europe	XER	Rest of Europe	TUR	Turkey
		XTW	Rest of the World				
LAM	*Latin America*	MEX	Mexico	BOL	Bolivia	CHL	Chile
		COL	Colombia	PER	Peru	XSM	Rest of South America
		CRI	Costa Rica	GTM	Guatemala	HND	Honduras
		NIC	Nicaragua	PAN	Panama	SLV	El Salvador
		XCA	Rest of Central America	DOM	Dominican Republic	JAM	Jamaica
		PRI	Puerto Rico	XCB	Caribbean	TTO	Trinidad and Tobago
OGA	*Oil/Gas exporting Countries*	ECU	Ecuador	VEN	Venezuela	BHR	Bahrain
		IRN	Iran	JOR	Jordan	KWT	Kuwait
		OMA	Oman	QAT	Qatar	SAU	Saudi Arabia
		ARE	United Arab Emirates	XWS	Rest of Western Asia	EGY	Egypt
		MAR	Morocco	TUN	Tunisia	XNF	Rest of North Africa
		NGA	Nigeria	XAC	South Central Africa		
ASO	*Asia and Oceania*	AUS	Australia	NZL	New Zealand	XOC	Rest of Oceania
		HKG	Hong Kong	JPN	Japan	KOR	Korea Republic of
		MNG	Mongolia	TWN	Taiwan	XEA	Rest of East Asia
		BRN	Brunei Darussalam	KHM	Cambodia	IDN	Indonesia
		LAO	Lao PDR	MYS	Malaysia	PHL	Philippines
		SGP	Singapore	THA	Thailand	VNM	Viet Nam
		XSE	Rest of Southeast Asia	BGD	Bangladesh	IND	India
		NPL	Nepal	PAK	Pakistan	LKA	Sri Lanka
		XSA	Rest of South Asia	KAZ	Kazakhstan	KGZ	Kyrgyzstan
		XSU	Rest of Former Soviet	ARM	Armenia	AZE	Azerbaijan
		GEO	Georgia	ISA	Israel		
AFR	*Africa*	BEN	Benin	BFA	Burkina Faso	CMR	Cameroon
		CIV	Cote d'Ivoire	GHA	Ghana	GIN	Guinea
		SEN	Senegal	TGO	Togo	XWF	Rest of Western Africa
		XCF	Central Africa	ETH	Ethiopia	KEN	Kenya
		MDG	Madagascar	MWI	Malawi	MUS	Mauritius
		MOZ	Mozambique	RWA	Rwanda	TZA	Tanzania
		UGA	Uganda	ZMB	Zambia	ZWE	Zimbabwe
		XEC	Rest of Eastern Africa	BWA	Botswana	NAM	Namibia
		ZAF	South Africa	XSC	Rest of South African CU		

For the modelling of the tariff reduction for renewable electricity technology (*Preferential Trade Agreement* scenario) in the CGE model, we remove the tariff on imports of sectoral outputs of Machinery and equipment (TEO) and Electronic equipment (TEC) from Europe, that are used in the renewable electricity sectors of Brazil. In the *Foreign Direct Investment* scenario, we assume the increase of new renewables to reach a share of 23% in the electricity generation mix of Brazil. We assign sector-specific domestic capital as input in each electricity technology and additional European capital input. The cost structure with domestic capital inputs and FDI as well as average annual generation for the different renewable technologies are given in Figure A-2. Annual FDI in renewables which is required to meet the NDC target sums up to 4.9 billion USD, which is quite substantial, compared to 11 billion USD of total average annual greenfield investments from the EU to Brazil in the period from 2006 to 2015 (APEX-BRASIL 2017). We further assume an increased capital effectiveness of European FDI compared to domestic capital inputs, implemented as less FDI input necessary to produce one unit of electricity output. The reduced FDI inputs for the different technologies are assumed to be 80% for hydro, 90% for biomass, and 20% for solar.

Figure A-2: Renewable electricity generation and cost from domestic and foreign direct investment.



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