The Carbon Footprint of Global Trade Imbalances

Hendrik Mahlkow* & Joschka Wanner†

July 2021

Abstract

A large share of global carbon emissions arises in the production of goods that are consumed in a different country. The flow of carbon embodied in trade is highly asymmetrical. At the same time, trade is highly and persistently unbalanced in value terms, too. Prominently, the two countries with the largest net ex- and imports of carbon (China and the US) have at the same time consistently been among the countries with the largest trade surplus and deficit, respectively. We investigate the effects of global trade imbalances on carbon emissions around the world. To this end, we use a Ricardian quantitative trade model including sectoral input-output linkages, trade imbalances, and carbon emissions from fossil fuel combustion. For every individual country, the emission effect of removing its trade imbalance depends on the carbon intensities of its production and consumption patterns, as well as on its fossil resource abundance. The simultaneous removal of all global trade imbalances is found to lower world carbon emissions by by 0.62 % or 184 million tons of carbon dioxide. Out of all individual countries' imbalances, eliminating the Qatari trade surplus and the US trade deficit would lead to the largest environmental benefits in terms of lower global emissions.

JEL-Codes: F14; F18; Q56
Keywords: Carbon emissions; international trade; gravity

*Kiel Institute of the World Economy, Contact: hendrik.mahlkow@ifw-kiel.de

†University of Potsdam, Kiel Institute of the World Economy, Contact: joschka.wanner@uni-potsdam.de.

1 Introduction

In 2016, the two countries with the largest trade deficits in the world (the United States and the United Kingdom) were at the same time the countries with the largest (US) and third-largest (UK) net imports of carbon emissions. China, on the other hand, had both the largest trade surplus and by far the largest amount of net exports of carbon emissions. The second largest net carbon exporter (Russia) also had a large trade surplus (8th largest in the world). Of course, there are other examples, like Germany and Japan that have large trade surpluses and are strong net carbon importers, or India, that has a large trade deficit but exports way more carbon than it imports. Still, the question arises whether global trade imbalances allow specialization and consumption patterns that magnify the global carbon footprint.

The question is not straightforward to answer. First off, maybe the United States and China are net importer and net exporter of carbon *only because* they are net importers and exporter overall, respectively. The data can give an answer to this if we consider the embodied emissions *per dollar* of exports and per dollar of imports, i.e. the ex- and import carbon *intensities*. Focusing on the two most prominent examples for now, it turns out that Chinese exports are about twice as carbon-intensive as its imports, while US exports are only about half as carbon-intensive as its imports. This pattern magnifies these countries' imbalances in embodied emissions in comparison to their trade value imbalances. It further suggests that there may be scope for lower overall emissions if a trade re-balancing limited the United States' possibility to buy more of its "dirty" imports than it sells comparably "clean" exports and put a constraint on China to act as the world's supplier of carbon-intensive products. However, eliminating trade imbalances would reshuffle trade and production all around the world and we cannot rule out a-priori that some of China's "dirty" production will end up in countries that produce the same products with an even larger use of fossil fuels and hence higher emissions. Therefore, if we want to know the "carbon footprint of global trade imbalances", we need to simulate the balancing of all current accounts in a quantitative model.

Beyond the differences in production vs. consumption carbon intensity, the previously mentioned role of Russia as a large net exporter points to an additional important dimension: the role of trade in fossil fuels. A considerable share of Russian exports is the sale of fossil fuels. The fact that the production of fossil fuels is itself carbon intensive shows up in the Russian carbon trade balance, the fact that the burning of these fossil fuels in their destination countries will cause additional emissions does not. The possibility to run a trade surplus enables fossil fuel exports like Russia to focus its production on fossil fuel extraction to a larger extent than they could if they had to align their production more strongly with their own consumption patterns. Global trade imbalances can therefore have important implications for fossil fuel *supply*, which also have to be taken into account in quantifying the imbalances' carbon footprint.

We use a Ricardian trade model along the lines of Eaton and Kortum (2002). In order to capture countries' full embedding into global value chains, we include a sectoral input-output structure as in Caliendo and Parro (2015). Additionally, we incorporate carbon emissions from fossil fuel combustion with varying carbon intensities for different types of fossil fuels. Together with the input-output structure, this allows a fine-grained consideration of embodied carbon flows and a clean distinction of countries' territorial emissions and carbon footprints. As an environmentally extended version of Caliendo and Parro (2015), the model is closely related to the contributions by Caron and Fally (2020) and Shapiro (2020), which in turn are the latest additions to a young, but growing literature incorporating emissions into structural gravity models (Egger and Nigai, 2015; Shapiro, 2016; Larch and Wanner, 2017, 2019; Shapiro and Walker, 2018).

We use the quantitative framework for two types of counterfactual analyses. First, we eliminate individual countries' trade imbalances, altering the rest of the world's surpluses and deficits only to the extent necessary to ensure that global supply equals global demand. We calculate both how the country's territorial emissions and footprint react to the elimination of the trade imbalance and how global emissions are affected. We use these country-level re-balancing exercises to identify patterns in countries' consumption habits and production specialization, as well as resource abundance that determine which imbalances are particularly problematic in terms of their effect on global emissions. Second, we simulate a global re-balancing in which all countries' surpluses and deficits are jointly erased. This allows us to assess whether the current pattern of trade imbalances around the world is in fact partly responsible for the high level of global carbon emissions. In addition to insights on the *level* of global emissions, this counterfactual is also informative concerning the *distribution* of carbon emissions across the globe and how this is shaped by trade imbalances. Our exercises come with one important disclaimer. Unlike a growing literature on the *sources* of trade imbalances (cf. Davis and Weinstein, 2002; Barattieri, 2014; Reyes-Heroles, 2016; Eugster, Jaumotte, MacDonald, and Piazza, 2020; Felbermayr and Yotov, 2021), our paper purely examines the *consequences* of their removal, standing in the tradition of Dekle, Eaton, and Kortum (2007, 2008). To this respect, we do not point towards a policy that would eliminate the imbalance, but we can calculate the magnitudes of the long-run adjustments that such a policy would entail.

Until now, the role of trade imbalance in shaping global emission patterns has received little attention. In their recent handbook chapter, Copeland et al. (2021) briefly refer to imbalances as one factor that could contribute to the outsourcing of emissions. Li, Chen, Li, Li, and Chen (2020) consider embodied energy in the US-Chinese *bilateral* trade imbalance, showing that the United States implicitly net import large amounts of energy from China.

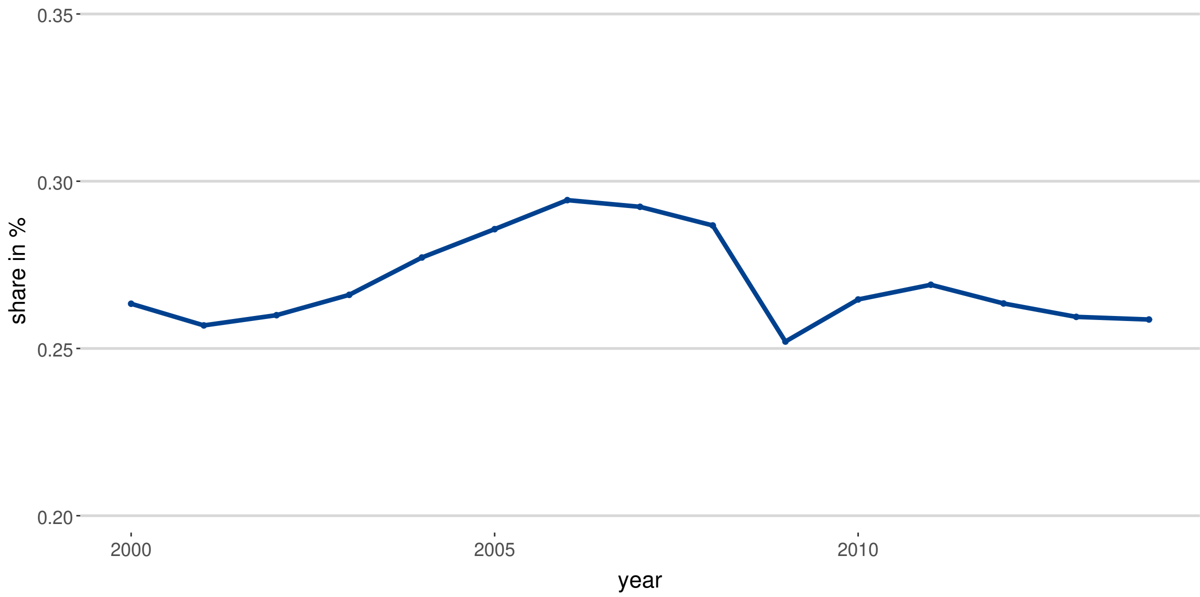
The remainder of this paper is structured as follows. Section 2 presents a collection of stylized facts about global trade imbalances in terms of both values and embodied emissions, their interrelation with one another and with the countries' resource abundance. Section 3 lays out the quantitative model and section 4 introduces the data used for the quantification. In section 5, we present the results of the counterfactual exercises. Section 6 concludes.

2 Trade Imbalances and Embodied Emissions: A Look at the Data

In this section, we take a look at the data and establish seven stylized facts about value and embodied emission trade imbalances across countries and time. While not novel individually and in part very straightforward, the aim of this *collection* of stylized facts is to motivate that trade imbalances have the potential to play an important role in shaping the level and distribution of global carbon emissions.

Stylized fact 1: A considerable share of global emissions is embodied in products that are traded internationally.

Figure 1: Share of Global CO2 Emissions Embodied in Trade, by Year

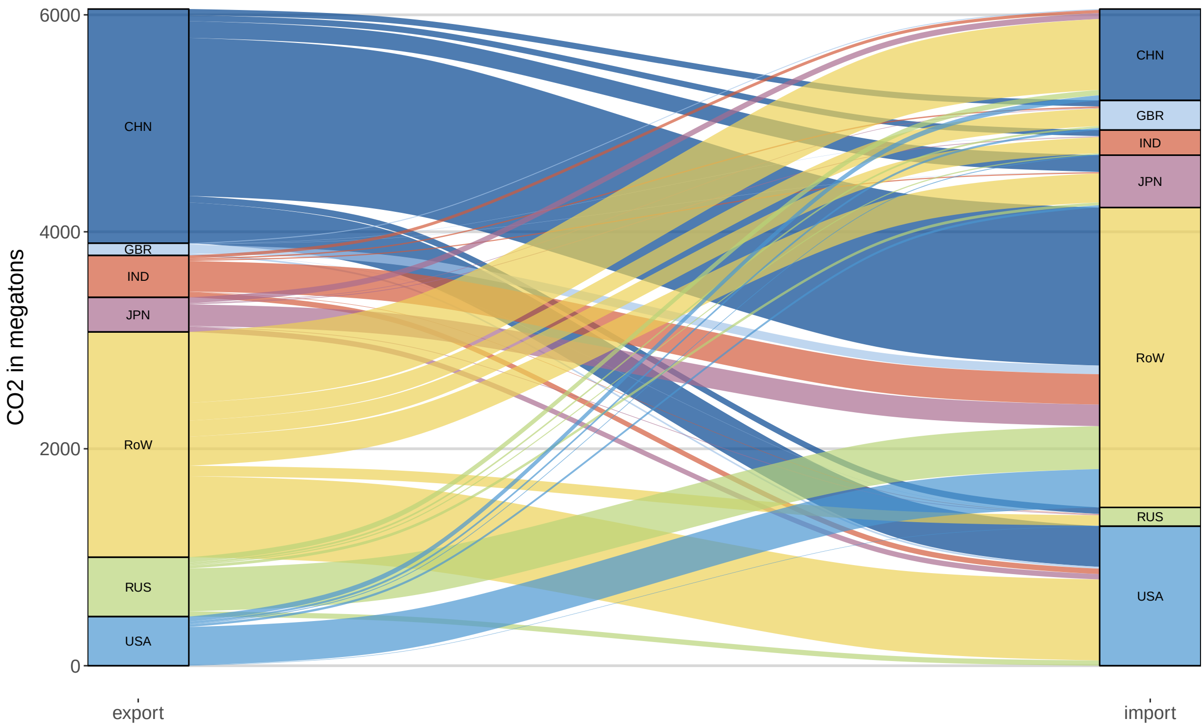


The first fact is important to establish the relevance of international trade in determining emission patterns around the world. If carbon emissions were overwhelmingly associated with products that are produced and consumed in the same countries, this would limit the role trade imbalances can play for carbon emissions. Figure 1 shows the share of carbon emissions embodied in international trade over time. It is calculated by dividing the embodied emissions in products that are traded internationally by global carbon emissions. The embodied emissions of traded goods include the emissions of their entire global value chain, including electricity and other intermediates, as well as their inputs and inputs to inputs, etc. Each dot represents one year for a period from 2000 to 2014.

As Figure 1 shows, 25 to 29 percent of global CO2 emissions are embodied in international trade. While some important sources of carbon emissions such as heating are necessarily local, a considerable share of emissions is embodied in products that are shipped internationally. Note that the range of values slightly deviates from Copeland, Shapiro, and Taylor (2021), who already establish this stylized fact and report a range from 24 to 35 percent between 1995 and 2009. This deviation is not surprising because we use a newer WIOD release (Timmer, Los, Stehrer, and De Vries, 2016).[1] In 2014 (i.e. the last year

[1]WIOD is also the data source of all stylized facts in section 2, despite stylized fact 7.

Figure 2: Bilateral Flows of Embodied CO2 Emissions in International Trade, 2014

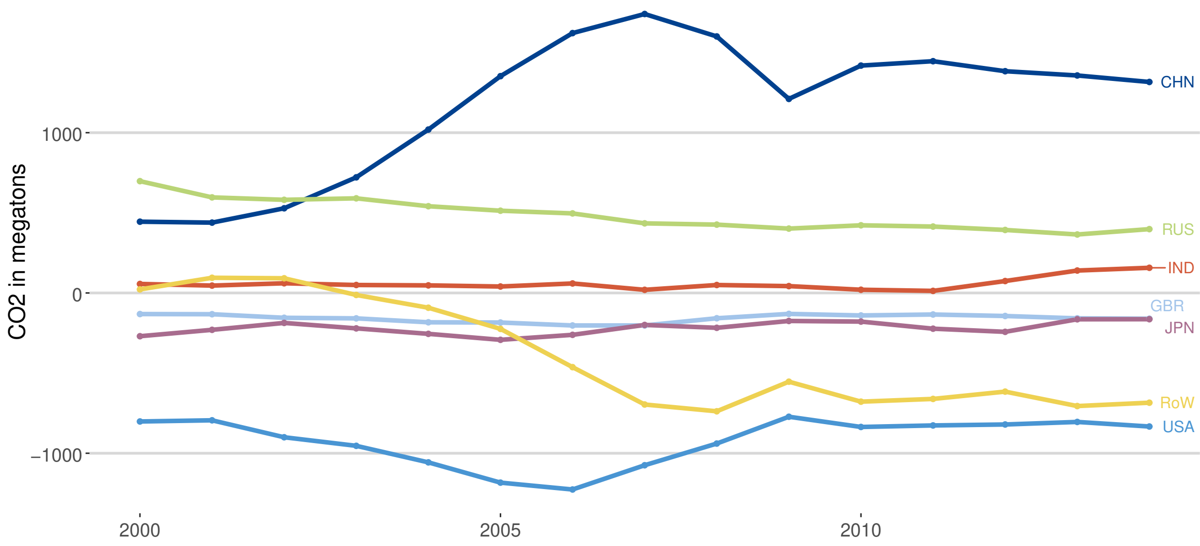


covered in this data set), the share of global CO2 emissions that were embodied in international trade was 26 percent.

Stylized fact 2: Embodied emissions in international trade are highly asymmetric.

Bilateral flows of embodied CO2 emissions for the six countries with the largest absolute imbalance of embodied carbon emissions in trade, plus an aggregated "Rest of the World", are depicted in Figure 2. The height of a country's box on the vertical axis relates to the corresponding total embodied emissions in their exports (left) and imports (right) in 2014. China, Great Britain, India, Japan, Russia and the USA account together for 66% of total embodied carbon emissions in exports and for 53% of total embodied carbon emissions in imports. For individual countries, the contrast can be very stark: while China exports 2158 megatons, it only imports 842 megatons of embodied CO2. For the US, the pattern is similarly extreme, but in the opposite direction. Their exports embody 453 megatons, while the embodied emissions in their imports amount to 1286 megatons of CO2. As the US, Great Britain and Japan are both net importers of embodied CO2, while India and

Figure 3: Embodied CO2 Emissions Imbalance in International Trade, by Year

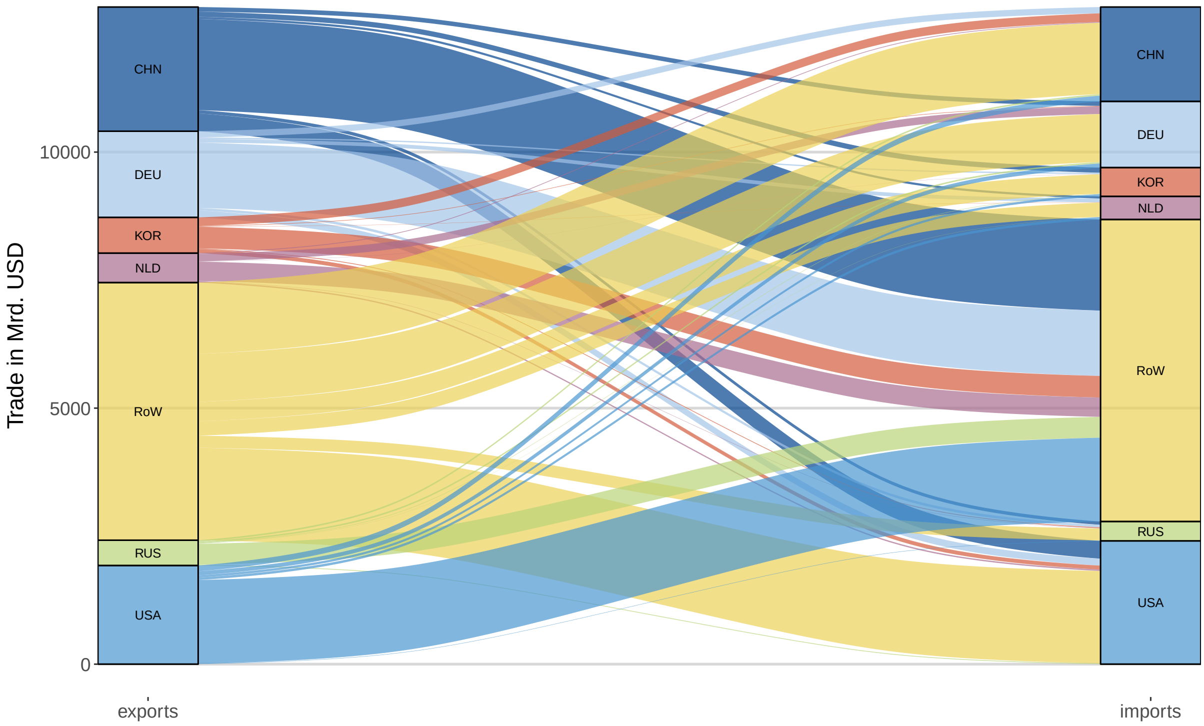


Russia are net exporters. Russia is also the country with the largest share of net exports to total exports in embodied emissions, which amount to 68 %, followed by China with 60 %. Figure 2 implies large gaps between territorial emissions, which stem from the production of goods, and carbon footprints, which account for the embodied emissions in consumed goods.

Stylized fact 3: The asymmetry in traded emissions is highly persistent.

Figure 3 depicts the imbalance of traded CO2 emissions embodied in exports and imports for the same countries as in Figure 2, but for the whole period from 2000 to 2014 rather than for just one point in time. All individual countries keep their role as a net ex- or importer of embodied emissions throughout the period. The United States are by far the largest net importer of emissions in all years and China overtakes Russia as the main net carbon exporter in 2003 and then takes a clear lead for all later years. This persistence magnifies the importance of understanding the role that the trade imbalances play in shaping global emissions. If trade imbalances contribute to a production and consumption pattern around the world that goes in hand with higher carbon emissions and this pattern persists over time, the resulting additional emissions will add up over time.

Figure 4: Bilateral Trade Flows, 2014



Stylized fact 4: Trade is highly asymmetric in value terms, too.

Figure 4 shows bilateral trade flows of goods and services of the six countries with the world's largest absolute trade imbalances. The height of a country's box on the vertical axis relates to their total exports (left) and imports (right) in billions of USD in 2014. It hence reproduces Figure 2, substituting embodied emissions for values. Even though the asymmetry in value trade is not as drastic as in embodied emissions trade, the value imbalances are substantial, too. China, Germany, South Korea, Netherlands, Russia and USA account together for **XX** % of total exports and **XX** % of total imports. China has a trade surplus of 583 bn USD, followed by Germany (390 bn), South Korea (135 bn), the Netherlands (124 bn), and Russia (114 bn). The USA have the largest trade deficit with 481 bn USD. Even though this stylized fact is well-established, we restate it here because it takes center-stage in our analysis which asks whether these well-known imbalances have an additional, so far overlooked environmental implication to them.

Stylized fact 5: Value trade imbalances are persistent, too.

Figure 5: Trade Imbalance, by Year

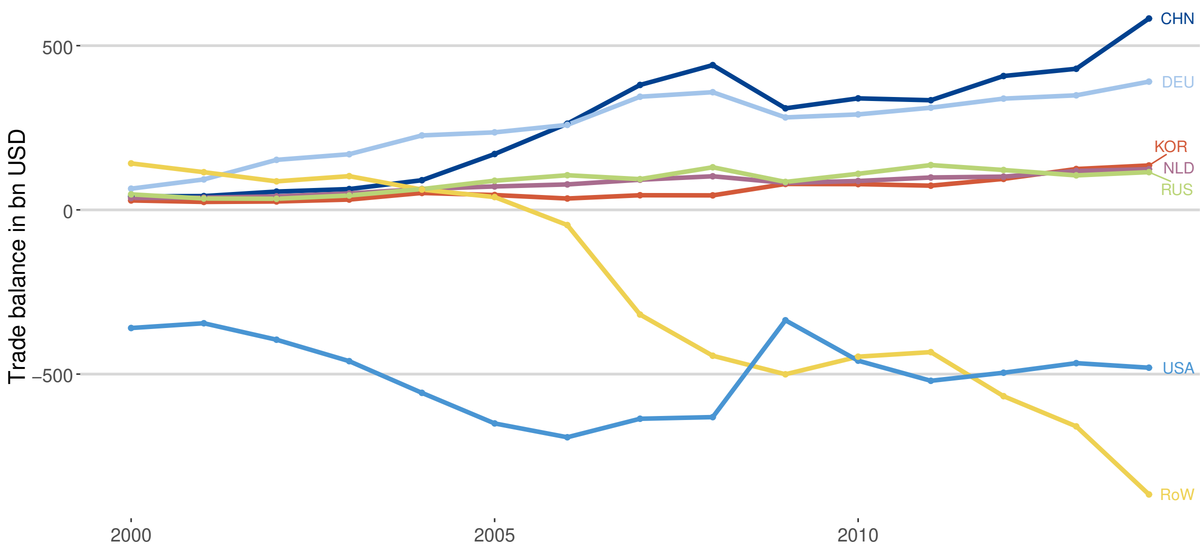
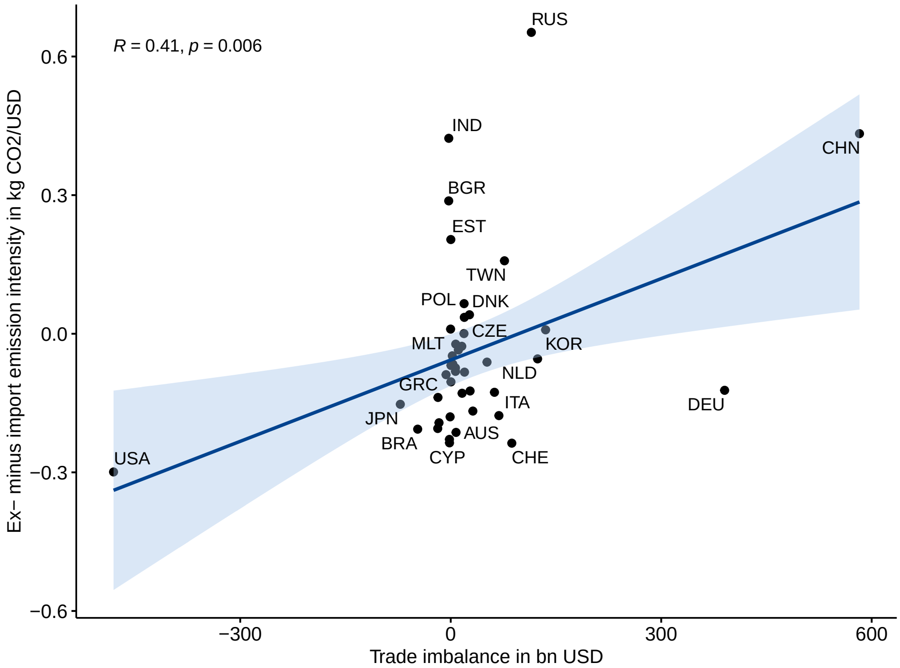


Figure 5 shows the annual trade imbalance in value terms of the same countries as in Figure 4 for the period 2000-2014. Similarly to the embodied emissions imbalances over time shown in Figure 3, a highly persistent pattern emerges. Though the fluctuations are somewhat larger, again none of the individual countries considered switches between net ex- and net importer status. The United States consistently run the by far largest trade deficit. China overtakes Germany as the world's largest net exporter in 2006 and keeps this first rank throughout the remaining period, though the gap to other countries is not as large in net value exports as in net carbon exports. If trade imbalances were a short-lived phenomenon, potential emission implications would be of little concern. This year's surpluses would turn into next year's deficits and a specialization pattern made possible in one year that leads to particularly high carbon emissions would be followed by a different pattern that would imply comparably low emissions. The persistence implies, however, that a high-emission global imbalance distribution could be a sustained phenomenon.

Stylized fact 6: The value trade imbalances and the relative carbon intensities of exports vs. imports are correlated.

In order to assess whether global trade imbalances are likely to drive world emissions up or down, we need to know which countries are running the deficits and which countries are

Figure 6: Correlation of Trade Imbalances and Carbon Intensities of Exports vs. Imports, 2014

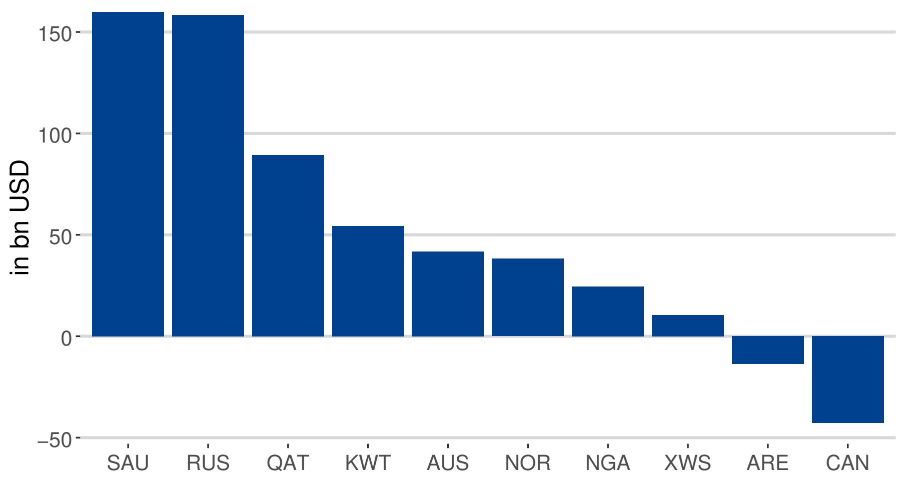


running the surpluses. If countries that sell less carbon-intensive products internationally than they buy were the surplus countries, imbalances might actually be environmentally beneficial. As Figure 6 makes clear, however, the opposite is true: the imbalances are positively correlated with the relative carbon-intensity of exports. Countries supplying "dirty" goods to the rest of world, while importing comparably clean products, tend to run surpluses. On the other hand, the countries exporting relatively "cleanly" tend to run deficits. Most clearly and most importantly, this pattern is evident for the United States and China, as we already briefly discussed in the introduction. The (imperfect) separation into clean deficit and dirty surplus countries strongly suggests that today's global trade imbalances contribute to upholding a trade pattern that implies higher carbon emissions than would prevail in a world of balanced trade.

Stylized fact 7: Many large fossil resource exporters are consistently running strong trade surpluses.

The relative carbon intensity of a country's production vs. consumption is not the only dimension that determines how the country's trade surplus or deficit impacts carbon

Figure 7: Trade Imbalance of the 10 Largest Fossil Exporters, 2014



emissions. Importantly, international trade is not only about products of varying carbon intensities, but it's also about the products use of which *causes* carbon emissions, namely fossil fuels. If countries that are rich in fossil resources run trade surpluses, this has the potential to drive up the global supply of fossil fuels and in turn the global level of emissions. As Figure 7 shows, this is exactly the case for many of the world's largest fossil fuel exporters.[2] Out of the top ten, eight countries have a trade surplus in 2014, which are partly huge in relation to these countries' overall GDPs.[3] It seems, therefore, that current global trade imbalances contribute to high carbon emissions in a second way, namely by fostering the global supply of fossil fuels.

To sum up, we have shown that international trade is highly unbalanced both in value and in embodied emissions terms. While this need not be bad news for global emission levels, the fact that there are positive associations between running a trade surplus and both exporting fossil-fuel intensive products and exporting fossil fuels, there is strong reason to suspect that the today's global imbalances are indeed driving up global carbon emissions and — given the persistence of the observed imbalances — will continue to do so. To quantitatively assess *the carbon footprint of global trade imbalances*, however, we need to take into account the equilibrium adjustments that would result from a global

[2]Based on GTAP 10. Fossil exports are calculating by summing up the export values of the *coal, oil* and *gas* sectors.

[3]Qatar's trade surplus is as high as 42 % of their GDP, followed by Kuwait (33 %), Saudi Arabia (21 %) and Russia (9 %).

rebalancing. In the following section, we present a model that will allow us to simulate such a rebalancing.

3 Model

We use a Ricardian quantitative trade model a la Eaton and Kortum (2002, henceforth EK), which incorporates a sectoral structure with input-output linkages, trade imbalances, and carbon emissions from fossil fuel combustion. It closely follows the sectoral extension of EK by Caliendo and Parro (2015, henceforth CP), but additionally includes carbon emissions from fossil fuel combustion in the production of other goods or for final consumption. As an environmental extension of the framework by CP, the model is also closely related to Shapiro (2020) and Caron and Fally (2020).

As our focus is on the effect of changes in trade imbalances (as in Dekle, Eaton, and Kortum, 2007, 2008), we will keep the expressions as simple as possible by not considering tariffs as in CP or other policy variables that would allow explicit climate policies (such as a carbon tax).

3.1 Preferences

There is a set of countries $\mathcal{N}$, denoted by i and n, one set of fossil fuel sectors, denoted by $f \in \mathcal{F}$ and $g \in \mathcal{F}$, and J other sectors, denoted by $j \in \mathcal{J}$ and $k \in \mathcal{J}$. In each sector, there is a continuum of goods $\omega^{f/j} \in [0,1]$. Households in n obtain utility from consumption C according to the following two-tier Cobb-Douglas utility function:

$$u_n = \prod_{f \in \mathcal{F}} \left(\exp \int_0^1 \ln C_n(\omega^f) d\omega^f \right)^{\alpha_n^f} \prod_{j \in \mathcal{J}} \left(\exp \int_0^1 \ln C_n(\omega^j) d\omega^j \right)^{\alpha_n^j},$$

where α is the constant sectoral expenditure share and $\alpha_n^f + \sum_{j \in \mathcal{J}} \alpha_n^j = 1$. Note that the choice of a lower-tier Cobb-Douglas instead of a more general CES utility function does not affect any results and is solely motivated by the attempt to keep parameters to the necessary minimum (see Eaton and Kortum, 2012, for the corresponding comparison in the one-sector EK framework). While the aggregation of utility from different varieties *within* one sector is the same for all countries, expenditures shares *across* sectors vary between countries, allowing for differently emission-intensive consumption patterns. This flexibility is crucial as the trade deficit or surplus of a country that consumes a lot of fossil fuels or products that require high fuel input in production will have different emission implications than the deficit or surplus of a country with a high share of clean services expenditure.

3.2 Production

Goods are produced using labour l and composite intermediate input bundles m from the fossil fuel sectors and from all other sectors. Countries differ in their productivity for different goods from the continua, inversely captured by the input requirement a, and the input cost shares γ. The production technology is Cobb-Douglas:

$$q_n(\omega^j) = \left[a_n(\omega^j)\right]^{-1} \left[l_n(\omega^j)\right]^{\gamma_n^j} \prod_{f \in \mathcal{F}} \left[m_n^f(\omega^j)\right]^{\gamma_n^{f,j}} \prod_{k \in \mathcal{J}} \left[m_n^k(\omega^j)\right]^{\gamma_n^{k,j}},$$
$$q_n(\omega^f) = \left[a_n(\omega^f)\right]^{-1} \left[l_n(\omega^f)\right]^{\gamma_n^f} \prod_{g \in \mathcal{F}} \left[m_n^g(\omega^g)\right]^{\gamma_n^{g,f}} \prod_{j \in \mathcal{J}} \left[m_n^j(\omega^f)\right]^{\gamma_n^{j,f}},$$

with $\gamma_n^j + \sum_{f \in \mathcal{F}} \gamma_n^{f,j} + \sum_{k \in \mathcal{J}} \gamma_n^{k,j} = 1$ and $\gamma_n^f + \sum_{g \in \mathcal{F}} \gamma_n^{g,f} + \sum_{j \in \mathcal{J}} \gamma_n^{j,f} = 1$ and the intermediate input bundles are themselves Cobb-Douglas composites[4]:

$$m_n^f = \exp \int_0^1 \ln d_n(\omega^f) d\omega^f \quad \text{and} \quad m_n^j = \exp \int_0^1 \ln d_n(\omega^j) d\omega^j,$$

where $d_n(\omega^f)$ and $d_n(\omega^j)$ are the demand for the specific varieties ω^f and ω^j as intermediate inputs. Unit costs (which equal the price due to perfect competition and constant returns to scale) in the regular and the fossil fuel sectors are given by $c_n^j a_n(\omega^j)$ and $c_n^f a_n(\omega^f)$, where the cost of the input bundles are given by

$$c_n^j = \Upsilon_n^j \left[w_n\right]^{\gamma_n^j} \prod_{f \in \mathcal{F}} \left[P_n^f\right]^{\gamma_n^{f,j}} \prod_{k \in \mathcal{J}} \left[P_n^k\right]^{\gamma_n^{k,j}}, \tag{1}$$

$$c_n^f = \Upsilon_n^f \left[w_n\right]^{\gamma_n^f} \prod_{g \in \mathcal{F}} \left[P_n^g\right]^{\gamma_n^{g,f}} \prod_{j \in \mathcal{J}} \left[P_n^j\right]^{\gamma_n^{j,f}}, \tag{2}$$

[4]Note that just as in the utility function, this could be generalized to a CES composite without changing any of the final results.

where $\Upsilon_n^j = (\gamma_n^j)^{-\gamma_n^j} \prod_{f\in\mathcal{F}} (\gamma_n^{f,j})^{-\gamma_n^{f,j}} \prod_{k\in\mathcal{J}} (\gamma_n^{k,j})^{-\gamma_n^{k,j}}$, w denotes the wage, P the price of a composite intermediate bundle, and $\Upsilon_n^f = (\gamma_n^f)^{-\gamma_n^f} \prod_{g\in\mathcal{F}} (\gamma_n^{g,f})^{-\gamma_n^{g,f}} \prod_{j\in\mathcal{J}} (\gamma_n^{j,f})^{-\gamma_n^{j,f}}$. Input requirement coefficients are assumed to be drawn from a type-III extreme value (Weibull) distribution, i.e. $Pr[a_i(\omega^j) \leq a] = 1 - \exp(-(A_i^j a)^{\theta^j})$ (and accordingly in the fossil fuel sectors), where A is a location parameter capturing the absolute advantage and θ is a dispersion parameter (inversely) capturing the extent of comparative advantage differences.[5]

Importantly, the production structure implies that countries not only differ in their productivities, but also in the extent to which they rely on fossil fuel inputs in producing different goods. Just as the differences in the "greenness" of consumption, this can have important implications for how a country's trade surplus/deficit affects global emissions: it can enable "dirty" (i.e. fossil fuel intensive) producers to serve a larger share of global demand or it can help them cover more of their own demand with cleaner products from abroad. Note also the two-layer structure of comparative advantage: the probabilistic EK notion of comparative advantage determines which countries produce which products *within* sectors and additionally, comparative advantage *across* sectors as determined by sectoral productivities and input costs determines which countries specialize into production in which sectors. In one important dimension, countries can specialize in producing fossil fuel intensive goods vs. products that rely on less fossil fuel inputs — with different implications for the consequences of the countries' trade imbalances on emissions. In a second dimension, countries can specialize in ordinary goods or in the *production* of fossil fuels. If countries of this latter (fossil resource abundant) type run a trade surplus, this increases global fossil fuel supply and hence drives up global emissions, pointing to a potentially problematic role of imbalances of fossil fuel exporters.

[5]Note that both EK and CP equivalently have countries draw productivities from a type-II extreme value (Frechet) distribution instead. We follow Eaton and Kortum (2012) here and use the original Ricardian technology measure of input requirements.

3.3 International Trade

3.3.1 Gravity

Both consumers and producers source the goods they buy from the lowest-cost supplier. International trade faces iceberg trade costs t^j_{ni} and t^f_{ni}, i.e. t units have to be shipped to deliver one unit from i to n. The cost distributions for country i delivering goods to country n depend on i's productivity and input costs, as well as on bilateral frictions between i and n and are given by

$$Pr[c_{ni}(\omega^j) \leq c] = 1 - e^{-(A^j_{ni}c)^{\theta^j}} \quad \text{and} \quad Pr[c_{ni}(\omega^f) \leq c] = 1 - e^{-(A^f_{ni}c)^{\theta^f}},$$

with $A^j_{ni} = A^j_i/(t^j_{ni}c^j_i)$ and $A^f_{ni} = A^f_i/(t^f_{ni}c^f_i)$. Country i is hence likelier to be able to provide goods at a low price to n if (i) its overall productivity in the respective sector is high (large A), (ii) its input costs are low (small c), and/or (iii) its trade costs with n are low (small t).

Under perfect competition, producers price at their costs. The price at which consumers and producers in country n end up buying a good ω is the minimum price across the bilateral cost distributions just shown. The resulting price distributions inherit the Weibull form from the technology and cost distributions and are given by:

$$F^j_n(p) = 1 - e^{-(\bar{A}^j_n p)^{\theta^j}} \quad \text{and} \quad F^f_n(p) = 1 - e^{-(\bar{A}^f_n p)^{\theta^f}},$$

with

$$\bar{A}^j_n = \left[\sum_{i \in \mathcal{N}} (A^j_{ni})^{\theta^j}\right]^{1/\theta^j} \quad \text{and} \quad \bar{A}^f_n = \left[\sum_{i \in \mathcal{N}} (A^f_{ni})^{\theta^f}\right]^{1/\theta^f}$$

The $\bar{A}$s summarize how the three price influences (technology, input costs, and geography as captured by the trade costs) *all around the world* shape the price level in a country. Specifically, we can obtain sectoral price indices by integrating over the price distributions:

$$P^j_n = \exp\left(\int_0^\infty \ln(p) dF^j_n(p)\right) = \frac{\exp(-\varepsilon/\theta^j)}{\bar{A}^j_n} \quad \text{and} \quad P^f_n = \frac{\exp(-\varepsilon/\theta^f)}{\bar{A}^f_n}, \tag{3}$$

where $\varepsilon = 0.5772\ldots$ is Euler's constant. Note that the possibility of non-tradable sectors is implicitly also captured. In these non-tradable sectors, trade costs are prohibitively high ($t^j_{ni} = \infty$) and the price hence simplifies to $P^j_n = \exp(-\varepsilon/\theta^j)/A^j_{nn}$.

Country n's total spending on goods from sector j and on fossil fuels are X^j_n and X^f_n. The shares of these expenditures that are spent on goods and fossil fuels from country i equals the share in which i is the lowest supplier and is given by a sectoral version of the EK gravity expression[6]:

$$\pi^j_{ni} = \frac{X^j_{ni}}{X^j_n} = \left(\frac{A^j_{ni}}{\bar{A}^j_n}\right)^{\theta^j} \quad \text{and} \quad \pi^f_{ni} = \frac{X^f_{ni}}{X^f_n} = \left(\frac{A^f_{ni}}{\bar{A}^f_n}\right)^{\theta^f}. \tag{4}$$

International trade links carbon emissions across countries in a direct and an indirect way. Directly, countries with a comparative advantage in fossil fuel intensive goods will specialize in the production of these goods, emit more CO_2, and tend to implicitly export more emissions to other countries than importing from them. Indirectly, emissions in different countries are additionally linked because the fossil fuels causing them are themselves traded. Lower (higher) demand for fossil fuels in one country will drive down (up) the price for fossil fuels and hence incentivize other countries to produce more (less) fossil fuel intensively.

3.3.2 Trade balance

Total expenditures for sector j and for fossil fuels f combine expenditure on intermediate bundles and for final consumption:

$$\begin{aligned} X^j_n &= \sum_{f\in\mathcal{F}} \gamma^{j,f}_n \sum_{i\in\mathcal{N}} X^f_i \pi^f_{in} + \sum_{k\in\mathcal{J}} \gamma^{j,k}_n \sum_{i\in\mathcal{N}} X^k_i \pi^k_{in} + \alpha^j_n I_n \quad \text{and} \\ X^f_n &= \sum_{g\in\mathcal{F}} \gamma^{f,g}_n \sum_{i\in\mathcal{N}} X^g_i \pi^g_{in} + \sum_{j\in\mathcal{J}} \gamma^{f,j}_n \sum_{i\in\mathcal{N}} X^j_i \pi^j_{in} + \alpha^f_n I_n, \end{aligned} \tag{5}$$

where the final absorption I_n consists of labour income (given by the total labour endowment L_n times the wage) and the trade deficit (D_n):

$$I_n = w_n L_n + D_n. \tag{6}$$

[6] As described in EK, this share can be calculated as the probability that i has the lowest costs of delivering a good ω to n: $Pr[c_{ni}(\omega^j) \leq \min\{c_{ns}(\omega^j); s \neq i\}] = \int_0^\infty \prod_{s\neq i}[\exp(-(A^j_{ns}c)^{\theta^j})]d(\exp(-(A^j_{ni}c)^{\theta^j}))$ (and in the fossil fuel sectors accordingly). To move to EK's explicit gravity equation for trade *flows*, multiply the trade shares with the destination country's total sectoral expenditure, solve the market clearing condition for $(A^j_i/c^j_i)^\theta$, substitute the expression into (4) and simplify using (3)

Trade is multilaterally balanced up to the exogenously given trade deficit:

$$\sum_{i\in\mathcal{N}}\left(\sum_{f\in\mathcal{F}}X_n^f\pi_{ni}^f+\sum_{j\in\mathcal{J}}X_n^j\pi_{ni}^j\right)-D_n=\sum_{i\in\mathcal{N}}\left(\sum_{f\in\mathcal{F}}X_i^f\pi_{in}^f+\sum_{j\in\mathcal{J}}X_i^j\pi_{in}^j\right). \tag{7}$$

International trade allows countries to decouple their production and consumption patterns. They can specialize in producing certain varieties and they can focus their production on the sectors in which they have a comparative advantage. At the same time, they are free to still consume a product basket that is determined by their preferences rather than their comparative advantage. Just because a country produces a lot of fossil fuels, it does not have to spend a large share of its income on these fuels. Trade balance puts a limit to the decoupling: the overall value of produced goods has to equal the overall value of the purchased ones. If a country wants to export another dollar worth of its products, it has to also import an additional dollar worth from elsewhere. With trade imbalances, the limit is softened. Up to the level of the deficit or surplus, they decouple not only *what* a country produces and buys, but also *how much*. The equilibrium effects of this further decoupling on carbon emissions are ambiguous. One country's surplus necessarily is another country's deficit. A deficit [surplus] will increase [lower] the respective country's carbon footprint. Globally, deficits in countries with "green" preferences, relatively "brown" production technologies, and large fossil resource endowments will tend to lower emissions, while deficits in countries demanding fossil-intensive products that produce with small fossil input shares will tend to increase them.

3.4 Equilibrium

The definition of an equilibrium closely mimics the expression by CP, slightly expanded by the presence of the fossil fuel sector.

Definition 1. *For given labour endowments L_n, technology parameters A_n^j and A_n^f, trade costs t_{ni}^j and t_{ni}^f, and trade imbalances D_n, an equilibrium is a set of wages w_n, composite intermediate goods prices P_n^j, and composite fossil fuel prices P_n^f that satisfy conditions* (1)–(7)*.*

3.4.1 Equilibrium in relative changes

Just as in CP, the determination of an equilibrium for a given policy change simplifies if, following Dekle, Eaton, and Kortum (2007, 2008), equilibrium conditions are re-expressed in terms of relative changes where possible. Denote values of any variable or parameter in the baseline equilibrium by x, under the counterfactual scenario by $x^{'}$, and its relative change by $\hat{x} = x^{'}/x$. Then, the equilibrium can be defined in relative changes as follows:

Definition 2. *Let* $\{w_n, P_n^j, P_n^f\}$ *be a baseline equilibrium for global trade imbalances* D_n *and* $\{w_n^{'}, P_n^{j'}, P_n^{f'}\}$ *be a counterfactual equilibrium for global trade imbalances* $D_n^{'}$*. Then,* $\{\hat{w}_n, \hat{P}_n^j, \hat{P}_n^f\}$ *satisfy the following equilibrium conditions* (8)–(13)*:*

Cost of the input bundles:

$$\hat{c}_n^j = [\hat{w}_n]^{\gamma_n^j} \left[\hat{P}_n^f\right]^{\gamma_n^{f,j}} \prod_{k=1}^{J} \left[\hat{P}_n^k\right]^{\gamma_n^{k,j}} \quad and \quad \hat{c}_n^f = [\hat{w}_n]^{\gamma_n^f} [\hat{p}_n^r]^{\gamma_n^{r,f}} \left[\hat{P}_n^f\right]^{\gamma_n^{f,f}} \prod_{j=1}^{J} \left[\hat{P}_n^j\right]^{\gamma_n^{j,f}} \tag{8}$$

Price indices:

$$\hat{P}_n^j = \left[\sum_{i=1}^{N} \pi_{ni}^j \left(\hat{c}_i^j\right)^{-\theta^j}\right]^{\frac{-1}{\theta^j}} \quad and \quad \hat{P}_n^f = \left[\sum_{i=1}^{N} \pi_{ni}^f \left(\hat{c}_i^f\right)^{-\theta^f}\right]^{\frac{-1}{\theta^f}} \tag{9}$$

Bilateral trade shares:

$$\hat{\pi}_{ni}^j = \left[\frac{\hat{c}_i^j}{\hat{P}_n^j}\right]^{-\theta^j} \quad and \quad \hat{\pi}_{ni}^f = \left[\frac{\hat{c}_i^f}{\hat{P}_n^f}\right]^{-\theta^f} \tag{10}$$

Total expenditure by country and sector:

$$\begin{aligned} X_n^{j'} &= \gamma_n^{j,f} \sum_{i=1}^{N} X_i^{f'} \pi_{in}^{f'} + \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^{k'} \pi_{in}^{k'} + \alpha_n^j I_n^{'} \quad and \\ X_n^{f'} &= \gamma_n^{f,f} \sum_{i=1}^{N} X_i^{f'} \pi_{in}^{f'} + \sum_{k=1}^{J} \gamma_n^{f,k} \sum_{i=1}^{N} X_i^{k'} \pi_{in}^{k'} + \alpha_n^f I_n^{'} \end{aligned} \tag{11}$$

Final absorption:

$$I_n^{'} = w_n^{'} L_n + p_n^{r'} R_n^{'} + D_n^{'} \tag{12}$$

Trade balance:

$$\sum_{i=1}^{N} X_n^{f'} \pi_{ni}^{f'} + \sum_{j=1}^{J} \sum_{i=1}^{N} X_n^{j'} \pi_{ni}^{j'} - D_n^{'} = \sum_{i=1}^{N} X_i^{f'} \pi_{in}^{f'} + \sum_{j=1}^{J} \sum_{i=1}^{N} X_i^{j'} \pi_{in}^{j'} \tag{13}$$

3.5 Carbon Emissions

Carbon emissions stem from fossil fuel combustion and are therefore modeled to be proportional to the usage of the fossil fuel composite, either as an intermediate in production or in final consumption, weighted by the varying carbon intensities ι^f of the different fossil fuel types. National emissions are hence given by

$$E_n = \sum_{f \in F} \iota^f \left(\int_0^1 \left(C_n(\omega^f) + \sum_{g \in \mathcal{F}} m_n^f(\omega^f) + \sum_{j \in \mathcal{J}} m_n^f(\omega^j) \right) d\omega^j \right) = \sum_{f \in \mathcal{F}} \frac{\iota^f X_n^f}{P_n^f}. \tag{14}$$

Note the difference to Shapiro (2020) who models emissions as being proportional to the *extraction* of fossil fuels. Linking emissions to the fossil fuel *usage* instead allows us to precisely track the emergence of emissions along the whole value chain.

3.6 Counterfactual Scenarios

The primary counterfactual analysis will consider the complete elimination of trade imbalances, i.e. a scenario in which $D_n^{'} = 0 \; \forall \; n$. Additionally, we will also consider what happens if only a specific individual country n eliminates its deficit or surplus. In this case, we need to make sure that world trade remains balanced. Specifically, if n was a surplus country initially, we calculate its share in the surpluses over all surplus countries. In the counterfactual scenario, we put its surplus to zero and lower all deficit countries' deficit by n's baseline share of the global surpluses. If n was a deficit country, we obtain its deficit share out of all trade deficits and proceed accordingly.

4 Data and Parametrization

To simulate the effects of a (simultaneous) removal of trade imbalances in general equilibrium, we need to identify the model parameters. Consumption shares and input coefficients (α, β, and γ), as well as bilateral trade shares (π), value added (wL), and initial trade imbalances (D) are obtained from input-output tables. Sectoral dispersion parameters (θ) are estimated based on the gravity equation following from the model. Carbon intensities of goods from fossil sectors (ι) are obtained from the literature.

Data Sources

We estimate and calibrate the model using various (standard) data sources. The main input for our simulation comes from the GTAP 10 database (Aguiar et al., 2019). The data supplies the model with all information that is needed from input-output tables (α, β, γ, π, wL, D) for the year 2014.[7] We choose the GTAP database because of its rich geographical (121 countries and 20 aggregated regions) and sectoral (65 sectors) coverage. It includes 5 fossil sectors (coal, oil, gas, petroleum and coal products, gas manufacture and distribution). For a full list of all sectors and countries see Appendix **XX**. All following data is concorded to the GTAP sectors and countries/regions.

5 Results

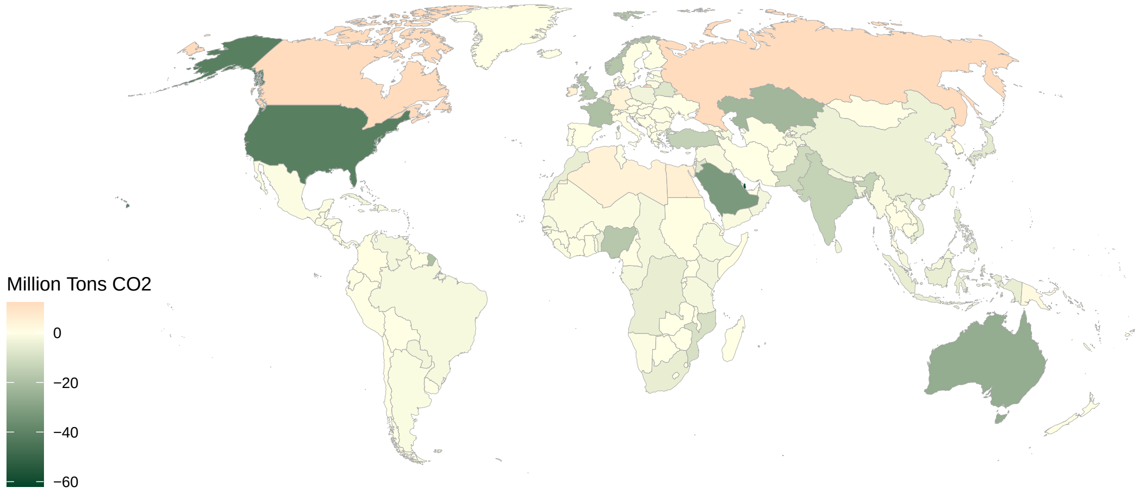
Quantitative trade models à la Eaton and Kortum (2002) allow the investigation of counterfactual scenarios, taking into account full general equilibrium effects. We use the model presented in section 3 to conduct scenarios in which we — partly of fully — re-balance global trade. We first simulate the elimination of an individual country's imbalance for each country separately in turn. Afterwards, we analyze the case of globally balanced trade, i.e. of a simultaneous elimination of all trade imbalances.

5.1 Balancing Individual Country's Trade Separately

In this section, we conduct a set of counterfactual experiments, in which we always set *one* country's trade imbalance to zero. For the removed trade imbalance of a single country the value of their imbalance is subtracted from the imbalances of the remaining 140 countries to ensure that world supply still equals world demand. If the single country has a trade

[7] This is the most recent year for which input-output data for 141 countries/regions is available. We do not predict baseline values for some future year since this would introduce additional margins of error.

Figure 8: Change in Global Carbon Emissions from the Removal of the Corresponding Country's Trade Imbalance, Each Country Balanced Separately



surplus the imbalances of trade deficit countries are reduced proportionally,[8] leaving the values of the other trade surplus countries unchanged. This is done vice versa if the single country has a trade deficit. As each country's individual trade re-balancing is separately considered here, this leads to 141 different counterfactuals.

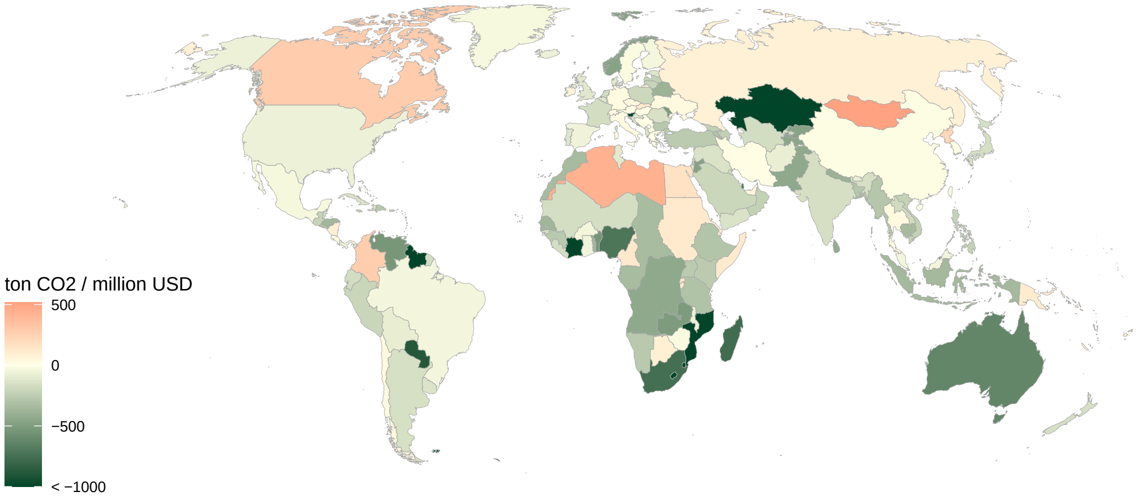
Figure 8 shows the change of global carbon emissions for all 141 counterfactuals. The value of each country represents the change in global carbon emission in the scenario where the respective country's imbalance is removed.[9] One thing that becomes apparent right away is the large effect on global emissions resulting from an elimination of the huge US trade deficit. As discussed in Section 2, the US not only import *more* than they export, but they also import clearly *more carbon-intensive* products. In line with the expectations, taking away the United States' possibility to sustain parts of their immense carbon footprint by consistently running a deficit indeed leads to a lower-emission new global production and consumption pattern. Specifically, global CO2 emissions would go down by 41.4 mio tons or XX percent.[10] This is roughly equivalent to XX's total annual emissions.

[8]If the trade surplus of a single country accounts for 2 % of all trade deficits, the trade imbalance of each deficit country is reduced by 2 %.

[9]For the exact values of the change in global carbon emissions see the second column of Table B1 in the appendix.

[10]All emission quantities refer to CO2 emissions only and to the model base year 2014.

Figure 9: Change in Global Carbon Emissions per Absolute Value of Removing Trade Imbalance per Country, Each Country Balanced Separately



The largest drop in global emissions, however, results from the elimination of the Qatari trade *surplus*. Bringing down Qatar's 90 billion US-Dollar surplus to zero would lower global emissions by 62 mio tons or XX percent. This is roughly equivalent to XX's total annual emissions. The Qatari example is linked to Stylized Fact 7 on fossil fuel exports running surpluses and the corresponding concern that this type of imbalance fosters global fossil fuel supply and therefore global emissions. Taking a further look at which countries' trade re-balancing lowers global emissions, the role of fossil fuel exports becomes even more evident: out of the top five countries, only the US have an initial deficit, while in all other cases the emission reductions result from bringing down surpluses of fossil fuel exporters, namely Qatar, Saudi-Arabia (32.6 mio tons world emission reduction), Australia (26.2 mio tons), and Kazakhstan (22.9 mio tons). The second- and third-largest global emission effects come from removing the imbalances of Saudi-Arabia and

Removing the trade imbalance of the following countries causes the highest global emission reduction: Qatar (62 mil tons CO2), USA (41.4), Saudi Arabia (32.6), Australia (26.2) and Kazakhstan (22.9). The highest increase in global emissions is caused by removing the trade imbalance of Russia (12.2 mil tons CO2), Canada (12), Egypt (5.7), Rest of East Asia (5) and Ireland (4.6).

Figure 10: Percentage Changes in Carbon Emissions, All Countries Balanced Simultaneously

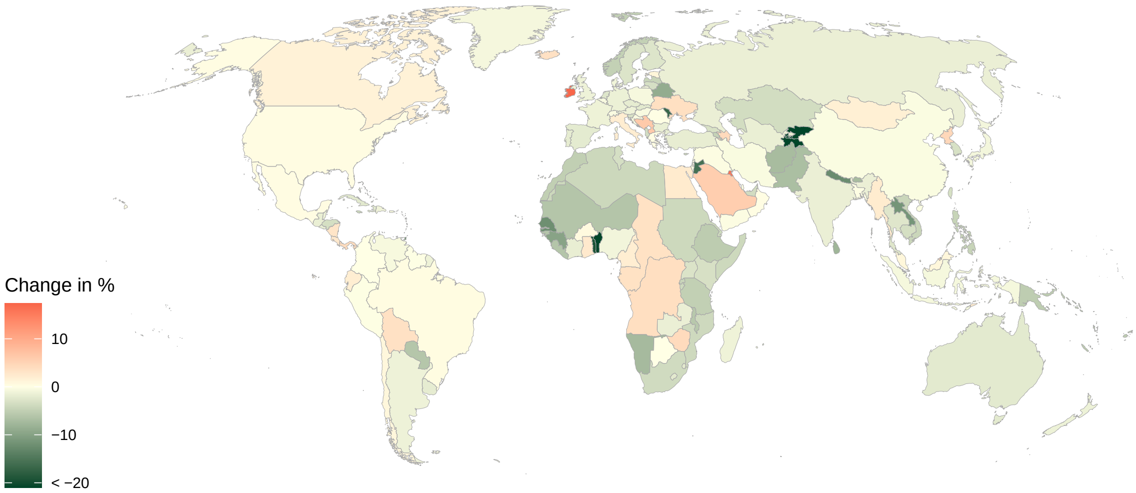


Figure 9 shows how global carbon emissions change per million USD of removed trade imbalance for 141 scenarios. For each country the relative "costs" of removing global emissions are depicted.[11] So to say the "most effective" removal happens in Cote d' Ivoire with a global emission reduction of 7460 tons CO2 per one million USD of removed trade imbalance followed by Slovenia (3705) and Mozambique (2791).[12]

5.2 All Countries Balanced Simultaneously

In our first counterfactual scenario, we set each trade imbalances of 141 countries and regions to zero simultaneously. Then the model is solved for equilibrium expenditures, prices, sectoral productions and total national incomes. Afterwards, percentage changes in carbon emissions, welfare and normalized trade flows are calculated.

Figure 10 and 11 show the most important results of the counterfactual removal of all trade imbalances simultaneously. The changes in carbon emissions of each country are given in Figure 10.[13] The effects are heterogeneous and range from an increase of 17 % in Ireland to a reduction of 46 % in Benin. Similarly, welfare changes are depicted in

[11] Exact values can be found in the last column of Table B1 in the appendix.

[12] Leaving aside small regions with a few countries (XTW, XSC, XSM)

[13] For the exact values of the change in carbon emissions and welfare see Table **??** in the Appendix

Figure 11: Percentage Changes in Welfare, All Countries Balanced Simultaneously

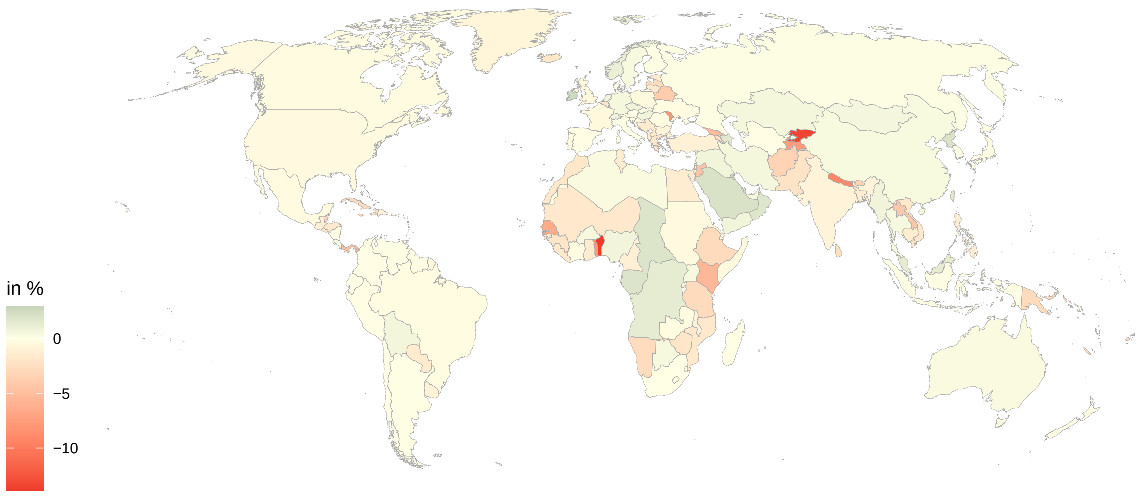
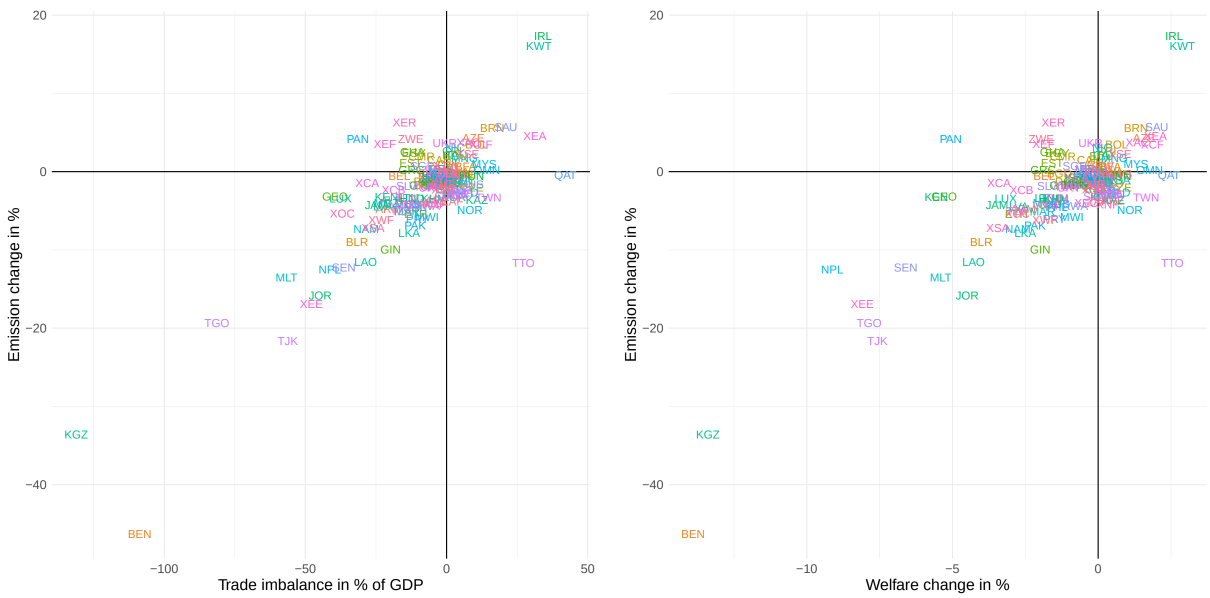


Figure 11 and range from an increase of 3 % in Kuwait to a decrease of 14 % in Benin. Comparing Figure 11 to Figure 10, one can see that countries who have welfare losses also decrease their emissions in general, e.g. Kazakhstan has the second highest relative welfare loss (13.4 %) and the second highest relative emission reduction (33.6 %). This pattern based on the condition that welfare losses are closely related to a decrease in production.[14] However, there are also countries that stand out from this general pattern. For example, Panama, Zimbabwe and Greece have welfare losses (-5.1 %, -2 %, -1.9 %) and emission increases (4.2 %, 4.2 %, 0.2 %). Out of 88 countries with negative welfare changes 74 countries decrease and 15 increase their emissions, see Figure 12. For countries with welfare gains the pattern does not hold. From the 51 countries 20 increase their emissions, e.g. Ireland has the second highest relative welfare gain (2.6 %) and the highest relative emission increase (17.3 %), and 32 decrease their emissions, e.g. Taiwan, Norway and Czech Republic have welfare gains (1.6 %, 1.1 %, 0.8 %) and decrease their emissions (-3.3 %, -4.9 %, -2 %).

Overall the simultaneous removal of all trade imbalances reduces global carbon emission by 0.62 % or 184.1 million ton CO2 per year. This is approximately equivalent to the emissions of Argentina.

[14]While a change in national income and price index also plays a role for the welfare effect, see section **??** for a detailed calculation.

Figure 12: Changes in Emissions and Trade Imbalances (left) and Changes in Welfare (right), All Countries Balanced Simultaneously



6 Conclusions

...

References

Aguiar, A., M. Chepeliev, E. L. Corong, R. McDougall, and D. van der Mensbrugghe (2019). The gtap data base: Version 10. *Journal of Global Economic Analysis 4*(1), 1–27.

Barattieri, A. (2014). Comparative advantage, service trade, and global imbalances. *Journal of International Economics 92*(1), 1–13.

Caliendo, L. and F. Parro (2015). Estimates of the Trade and Welfare Effects of NAFTA. *Review of Economic Studies 82*(1), 1–44.

Caron, J. and T. Fally (2020). Per Capita Income, Consumption Patterns, and CO2 Emissions. *Journal of the Association of Environmental and Resource Economists*.

Copeland, B. R., J. S. Shapiro, and M. S. Taylor (2021, May). Globalization and the Environment. NBER Working Papers 28797, National Bureau of Economic Research, Inc.

Davis, D. R. and D. E. Weinstein (2002). The mystery of the excess trade (balances). *American Economic Review 92*(2), 170–174.

Dekle, R., J. Eaton, and S. Kortum (2007). Unbalanced Trade. *American Economic Review: Papers and Proceedings 97*(2), 351–355.

Dekle, R., J. Eaton, and S. Kortum (2008). Global Rebalancing with Gravity: Measuring the Burden of Adjustment. *IMF Staff Papers 55*(3), 511–540.

Eaton, J. and S. Kortum (2002). Technology, Geography, and Trade. *Econometrica 70*(5), 1741–1779.

Eaton, J. and S. Kortum (2012). Putting Ricardo to Work. *Journal of Economic Perspectives 26*(2), 65–90.

Egger, P. and S. Nigai (2015). Energy Demand and Trade in General Equilibrium. *Environmental and Resource Economics 60*(2), 191–213.

Eugster, J. L., F. Jaumotte, M. MacDonald, and R. Piazza (2020). Are bilateral trade balances irrelevant?

Felbermayr, G. and Y. V. Yotov (2021). From theory to policy with gravitas: a solution to the mystery of the excess trade balances. *Kiel Working Paper 2138*.

Larch, M. and J. Wanner (2017). Carbon Tariffs: An Analysis of the Trade, Welfare, and Emission Effects. *Journal of International Economics 109*, 195–213.

Larch, M. and J. Wanner (2019). The Consequences of Unilateral Withdrawals from the Paris Agreement. *CESifo Working Paper 7804*.

Reyes-Heroles, R. (2016). The role of trade costs in the surge of trade imbalances. *Princeton University, mimeograph*.

Shapiro, J. S. (2016). Trade Costs, CO2, and the Environment. *American Economic Journal: Economic Policy 8*(4), 220–254.

Shapiro, J. S. (2020). The Environmental Bias of Trade Policy. *Quarterly Journal of Economics*.

Shapiro, J. S. and R. Walker (2018). Why is Pollution from U.S. Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade. *American Economic Review 108*(12), 3814–3854.

Timmer, M., B. Los, R. Stehrer, and G. De Vries (2016). An anatomy of the global trade slowdown based on the wiod 2016 release. Technical report, Groningen Growth and Development Centre, University of Groningen.

Appendix

A Regional and Sectoral Breakdown

Table A1: GTAP 10 data overview, year 2014

GTAP code	Country	Trade imbalance	Value added	Emissions
		in mil. USD		in mil. tons
ALB	Albania	-2343.17	11955.50	4.35
ARE	United Arab Emirates	-13680.01	396477.27	161.17
ARG	Argentina	6767.33	524917.01	187.40
ARM	Armenia	-2253.64	10944.23	5.27
AUS	Australia	41754.88	1383609.54	372.34
AUT	Austria	2235.27	391237.43	55.29
AZE	Azerbaijan	7088.01	74423.94	33.13
BEL	Belgium	-75638.19	452280.68	99.50
BEN	Benin	-7743.74	7123.36	5.59
BFA	Burkina Faso	769.18	11402.38	2.52
BGD	Bangladesh	-9735.54	169376.85	60.52
BGR	Bulgaria	-3655.52	51136.79	41.03
BHR	Bahrain	-967.56	33915.49	28.59
BLR	Belarus	-20848.68	65749.51	56.60
BOL	Bolivia	3407.70	31822.74	18.27
BRA	Brazil	-41415.40	2223440.86	450.83
BRN	Brunei	2809.08	17369.52	7.86
BWA	Botswana	573.03	16020.92	6.78
CAN	Canada	-42865.02	1687535.52	574.32
CHE	Switzerland	39130.01	689491.09	40.18
CHL	Chile	2001.82	240799.03	80.55
CHN	China	486436.24	9602143.61	7974.83
CIV	CÃ´te dâIvoire	-27.16	32265.88	9.24
CMR	Cameroon	-2550.08	28760.74	6.78
COL	Colombia	-2955.56	357556.80	73.95
CRI	Costa Rica	933.08	47342.48	7.28
CYP	Cyprus	-2319.61	22611.49	11.90
CZE	Czechia	17142.39	190182.19	85.92
DEU	Germany	180357.17	3507375.98	678.33
DNK	Denmark	1973.72	295647.05	51.79
DOM	Dominican Republic	-4123.47	59480.13	18.91
ECU	Ecuador	3069.28	99092.79	35.77
EGY	Egypt	-34352.70	296185.65	170.26
ESP	Spain	1567.14	1296336.14	237.55

Continued on next page

Table A1: GTAP 10 data overview, year 2014

GTAP code	Country	Trade imbalance	Value added	Emissions
		in mil. USD		in mil. tons
EST	Estonia	-2864.61	22522.75	8.19
ETH	Ethiopia	-5733.23	52814.50	10.84
FIN	Finland	4267.87	245216.25	48.57
FRA	France	-115212.47	2610786.47	318.43
GBR	United Kingdom	-159068.00	2773050.42	427.35
GEO	Georgia	-5866.56	14859.54	9.05
GHA	Ghana	-4250.62	35221.30	10.97
GIN	Guinea	-1078.71	5447.10	1.31
GRC	Greece	-26502.13	212833.95	153.40
GTM	Guatemala	-5006.40	57511.50	15.30
HKG	Hong Kong SAR China	-13311.66	276082.48	91.95
HND	Honduras	-2306.79	18989.88	8.45
HRV	Croatia	-2247.68	50418.22	17.14
HUN	Hungary	11142.13	124501.45	39.43
IDN	Indonesia	14934.51	869277.45	441.79
IND	India	-89042.61	1927078.40	1911.86
IRL	Ireland	80504.42	235671.17	44.22
IRN	Iran	11337.32	406410.50	537.07
ISR	Israel	-14890.39	265342.99	64.54
ITA	Italy	27763.05	1981906.70	318.51
JAM	Jamaica	-3075.55	12345.18	7.61
JOR	Jordan	-14870.84	33216.81	26.23
JPN	Japan	-40463.91	4496999.61	1015.52
KAZ	Kazakhstan	22842.54	212836.39	230.96
KEN	Kenya	-12445.88	58615.36	14.77
KGZ	Kyrgyzstan	-8645.19	6591.34	8.35
KHM	Cambodia	-717.44	16156.26	7.71
KOR	South Korea	33287.68	1264253.41	498.85
KWT	Kuwait	54383.94	166433.37	81.08
LAO	Laos	-3260.90	11371.35	3.63
LKA	Sri Lanka	-9684.13	73173.07	25.63
LTU	Lithuania	-5655.22	41695.97	10.84
LUX	Luxembourg	-22250.18	59276.12	14.91
LVA	Latvia	-5928.41	26242.71	8.93
MAR	Morocco	-15237.54	108965.53	53.36
MDG	Madagascar	84.99	10808.26	2.42
MEX	Mexico	-25813.56	1240187.92	419.72
MLT	Malta	-5141.55	9068.52	3.67
MNG	Mongolia	737.81	11647.75	18.55
MOZ	Mozambique	-3419.97	16075.36	4.16

Continued on next page

Table A1: GTAP 10 data overview, year 2014

GTAP code	Country	Trade imbalance	Value added	Emissions
		in mil. USD		in mil. tons
MUS	Mauritius	-1635.71	11840.63	5.13
MWI	Malawi	-400.42	5798.70	1.23
MYS	Malaysia	43928.97	329384.90	236.36
NAM	Namibia	-3470.27	12194.49	3.47
NGA	Nigeria	24450.11	563445.83	64.72
NIC	Nicaragua	339.11	11248.33	4.46
NLD	Netherlands	57425.84	793149.80	168.82
NOR	Norway	38212.65	462284.34	65.58
NPL	Nepal	-7243.16	17515.64	5.84
NZL	New Zealand	1172.31	184257.30	33.44
OMN	Oman	11749.45	82402.18	60.08
PAK	Pakistan	-26289.47	237314.81	136.53
PAN	Panama	-14494.16	46132.15	34.21
PER	Peru	-1288.76	202884.75	48.80
PHL	Philippines	-30528.28	270383.40	97.49
POL	Poland	-16574.43	485927.38	264.38
PRI	Puerto Rico	-2433.09	103199.22	12.82
PRT	Portugal	-5649.24	207528.84	50.10
PRY	Paraguay	-2982.68	29076.10	5.02
QAT	Qatar	89336.88	212153.87	78.49
ROU	Romania	-3217.68	188881.74	65.06
RUS	Russia	158412.95	1764105.40	1409.07
RWA	Rwanda	-503.33	7323.00	1.55
SAU	Saudi Arabia	159977.67	761199.96	396.69
SEN	Senegal	-5103.72	14027.11	6.12
SGP	Singapore	-21924.48	255084.00	81.45
SLV	El Salvador	-3413.68	24084.58	6.62
SVK	Slovakia	4012.25	94282.90	23.27
SVN	Slovenia	-54.56	44199.00	13.13
SWE	Sweden	15726.35	513837.91	39.99
TGO	Togo	-2616.31	3216.94	2.24
THA	Thailand	20989.16	382998.51	277.38
TJK	Tajikistan	-4817.78	8565.34	4.56
TTO	Trinidad & Tobago	7785.93	28594.72	23.31
TUN	Tunisia	-6031.78	43283.79	25.05
TUR	Turkey	-55433.58	739319.88	304.85
TWN	Taiwan	78490.48	528385.13	233.53
TZA	Tanzania	-6812.45	42772.13	10.02
UGA	Uganda	791.62	26364.69	5.35
UKR	Ukraine	-768.69	119162.30	207.93

Continued on next page

Table A1: GTAP 10 data overview, year 2014

GTAP code	Country	Trade imbalance	Value added	Emissions
		in mil. USD		in mil. tons
URY	Uruguay	-2994.28	51908.09	6.14
USA	United States	-606902.14	17031479.03	5155.36
VEN	Venezuela	4578.56	493900.27	159.62
VNM	Vietnam	-22826.69	169502.70	138.78
XAC	XAC	11794.61	153467.99	23.78
XCA	XCA	-383.37	1363.17	0.27
XCB	XCB	-20814.46	110943.50	32.01
XCF	XCF	7257.54	59346.94	12.69
XEA	XEA	22412.17	71607.85	68.89
XEC	XEC	-3952.84	75903.17	16.76
XEE	XEE	-3192.33	6667.55	7.26
XEF	XEF	-4517.72	20698.33	4.61
XER	XER	-14837.16	99779.93	77.81
XNA	XNA	-423.75	7444.20	1.70
XNF	XNF	-10203.01	241004.49	164.84
XOC	XOC	-16575.14	44920.10	17.16
XSA	XSA	-5984.77	22988.63	8.08
XSC	XSC	-68.47	6280.47	1.31
XSE	XSE	5034.34	67083.96	20.84
XSM	XSM	67.09	12729.08	2.98
XSU	XSU	-2445.80	100485.37	163.13
XTW	XTW	-0.18	154.35	0.06
XWF	XWF	-7479.29	32291.07	8.61
XWS	XWS	10497.11	347602.94	182.46
ZAF	South Africa	7021.02	329231.36	425.38
ZMB	Zambia	-245.07	25946.87	3.07
ZWE	Zimbabwe	-1764.41	13942.35	11.26

B Results

Table B1: Results Emission Change

	All countries balanced	Each country balanced	
Country	Emission change	Global emission change	
	in %	in mil tons	in tons / mil USD
ALB	-3.66	-0.34	-142.99
ARE	-3.66	0.69	50.68
ARG	-1.35	-1.07	-157.49
ARM	-4.73	-0.69	-304.71
AUS	-2.21	-26.17	-626.66
AUT	-1.35	0.01	5.99
AZE	4.32	-1.66	-234.55
BEL	-0.54	-9.23	-122.09
BEN	-46.28	-4.24	-547.26
BFA	0.65	-0.03	-45.28
BGD	-0.19	-2.81	-288.34
BGR	-1.66	-1.02	-279.63
BHR	-1.49	0.15	160.14
BLR	-8.95	-8.08	-387.34
BOL	3.51	-0.29	-84.17
BRA	0.38	-1.84	-44.35
BRN	5.57	-1.59	-567.40
BWA	-0.02	0.05	86.31
CAN	1.51	12.05	281.09
CHE	-0.37	1.35	34.49
CHL	0.96	0.07	35.65
CHN	-0.36	-4.35	-8.93
CIV	-1.79	-0.20	-7460.41
CMR	1.95	0.34	131.93
COL	-0.02	0.81	272.56
CRI	2.69	0.01	13.22
CYP	-4.19	-0.31	-131.64
CZE	-1.98	0.54	31.70
DEU	-1.50	4.08	22.60
DNK	-1.10	-0.22	-111.78
DOM	-1.22	-1.12	-272.09
ECU	1.99	-0.53	-172.34
EGY	2.37	5.67	165.12
ESP	-2.14	-0.09	-58.14
EST	1.11	-0.37	-129.23
ETH	-5.37	-1.69	-295.19
FIN	-2.76	-0.18	-42.02

Continued on next page

Table B1: Results Emission Change

	All countries balanced	Each country balanced	
Country	Emission change	Global emission change	
	in %	in mil tons	in tons / mil USD
FRA	-1.40	-19.69	-170.93
GBR	-1.34	-18.43	-115.87
GEO	-3.19	-1.40	-238.12
GHA	2.55	-0.23	-54.59
GIN	-9.91	-0.29	-270.82
GRC	0.25	0.00	0.03
GTM	-1.73	-1.08	-215.40
HKG	-1.65	-2.02	-151.42
HND	-3.40	-0.84	-364.02
HRV	-0.60	-0.26	-113.80
HUN	-0.53	0.06	5.45
IDN	-0.78	-5.29	-354.35
IND	-1.62	-14.20	-159.52
IRL	17.35	4.62	57.37
IRN	-0.46	0.13	11.67
ISR	-0.71	-1.88	-126.51
ITA	2.14	0.56	20.27
JAM	-4.27	-0.73	-238.64
JOR	-15.79	-7.16	-481.56
JPN	-0.94	-6.50	-160.68
KAZ	-3.63	-22.89	-1001.91
KEN	-3.22	-3.25	-261.09
KGZ	-33.60	-4.11	-475.40
KHM	-3.41	-0.25	-344.16
KOR	-3.21	-0.29	-8.68
KWT	16.11	-9.52	-175.03
LAO	-11.51	-0.58	-178.26
LKA	-7.83	-4.05	-417.83
LTU	-3.36	-1.27	-224.08
LUX	-3.42	-2.03	-91.05
LVA	-4.44	-1.38	-233.48
MAR	-5.05	-5.23	-342.93
MDG	-1.25	-0.07	-772.68
MEX	0.33	-0.90	-34.84
MLT	-13.51	-0.77	-149.83
MNG	1.78	0.38	516.52
MOZ	-3.99	-9.55	-2791.35
MUS	-4.10	-0.41	-250.43
MWI	-5.80	-0.03	-66.90

Continued on next page

Table B1: Results Emission Change

	All countries balanced	Each country balanced	
Country	Emission change	Global emission change	
	in %	in mil tons	in tons / mil USD
MYS	1.00	-2.13	-48.60
NAM	-7.34	-0.95	-274.96
NGA	-1.04	-17.63	-720.96
NIC	3.09	0.03	92.18
NLD	-2.65	-10.30	-179.29
NOR	-4.90	-18.08	-473.15
NPL	-12.51	-2.84	-391.67
NZL	-1.41	-0.19	-158.40
OMN	0.25	-2.75	-233.76
PAK	-6.86	-11.59	-440.71
PAN	4.17	-0.93	-64.32
PER	-0.15	-0.27	-208.23
PHL	-4.53	-6.96	-227.95
POL	-0.73	-3.26	-196.98
PRI	-0.97	-0.60	-236.30
PRT	-2.02	-0.74	-130.66
PRY	-6.01	-2.65	-887.71
QAT	-0.42	-61.98	-693.76
ROU	-0.11	-0.48	-149.33
RUS	-1.62	12.20	77.00
RWA	-4.39	0.07	146.53
SAU	5.75	-32.55	-203.49
SEN	-12.21	-1.91	-373.89
SGP	0.72	-1.44	-65.50
SLV	-1.81	-1.06	-309.26
SVK	-2.30	0.52	129.72
SVN	-3.14	-0.20	-3704.70
SWE	-2.84	-0.37	-23.29
TGO	-19.31	-0.98	-374.63
THA	-2.60	0.67	31.85
TJK	-21.63	-2.21	-458.46
TTO	-11.65	-2.91	-373.32
TUN	-3.38	-0.62	-103.27
TUR	-1.87	-14.56	-262.60
TWN	-3.30	-1.69	-21.59
TZA	-5.00	-2.06	-302.21
UGA	-2.93	-0.21	-269.90
UKR	3.71	0.02	28.88
URY	-2.01	-0.42	-140.16

Continued on next page

Table B1: Results Emission Change

	All countries balanced	Each country balanced	
Country	Emission change	Global emission change	
	in %	in mil tons	in tons / mil USD
USA	0.30	-41.41	-68.25
VEN	-0.65	-2.47	-539.23
VNM	-4.32	-5.34	-233.80
XAC	3.76	-5.20	-441.08
XCA	-1.42	-0.07	-176.13
XCB	-2.35	-2.92	-140.07
XCF	3.47	-2.46	-338.70
XEA	4.56	4.97	221.95
XEC	-4.02	0.47	117.71
XEE	-16.89	-1.66	-519.95
XEF	3.54	-0.31	-68.44
XER	6.27	0.03	1.85
XNA	-0.80	-0.01	-31.09
XNF	-4.17	4.47	438.54
XOC	-5.31	1.79	107.79
XSA	-7.16	-0.49	-81.09
XSC	-2.28	-0.34	-4893.86
XSE	2.27	-1.45	-288.21
XSM	-0.13	-0.19	-2863.16
XSU	-1.70	-0.42	-170.55
XTW	0.71	-0.20	-1105817.18
XWF	-6.13	-1.23	-165.03
XWS	-0.28	-1.51	-143.84
ZAF	-3.79	-5.30	-755.02
ZMB	-1.63	-0.13	-512.47
ZWE	4.20	-0.04	-22.52