The Role of Global Value Chains in Outsourcing Greenhouse Gas Emissions

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Abstract

This paper tracks the greenhouse gas emissions embedded in global value chains observing 186 countries from 1990 to 2015 and then look at the determinants of the emissions considering both country and sector level variables in a gravity like framework. Our graphical visualization displays that as expectedly, developed countries appear to be both major GHG emission producers and outsourcers in the highly fragmented world. Indeed, trade activities of China, the USA, Germany, Japan, and Russia contribute 40% of total global emissions. Moreover, our empirical results reveal that while higher capital stock is attributable to higher greenhouse gas emissions embedded in GVCs, renewable energy consumption of sectors can be seen as an emission decreasing factor. While higher income and financial development levels seem to decrease air quality, regional or global integration in trade agreements seems to be consistent with the current increasing efforts and concerns regarding environmental issues. Given the current trajectory and the findings of this article; negotiating environmental policies across nations, adaptation of greener production technologies in production process, and cost sharing plans between governments and producers should be carefully considered to decrease environmental degradation as well as to sustain natural resources.

Keywords: Greenhouse gas emissions, GVCs, backward linkages, forward linkages, emission intensity

JEL Codes: Q01, Q27, Q56

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1. Introduction

The sustainable growth literature has drawn substantial attention on global warming, air quality, and emission of harmful gases within the trade context. Several environmentally related terms are the main motives for trade policies nowadays (the EU's carbon border tariff under 'Fit for 55' package (BBC, 2021), the proposal of the US about tariffs on carbon-intensive imports (Bloomberg, 2021)). In the literature, studies can be divided into two main categories: (i) trade-environment nexus (see Grossman and Krueger, 1995; Dinda, 2004; Dinda and Coondoo, 2006 for the Environmental Kuznets Curve and pollution heaven hypothesis) and (ii) with a rapid growth in international trade and developments in global production networks, the global value chains (GVCs) related studies tracking the environmental impacts of sectors over their production stages until their final consumption in the framework of input-output models, which is known as the economic input-output life-cycle assessment (Hendrickson et al., 2006).

The first group of the literature asserts that expansion of economic activity and thereby trade can intensify environmental pollution. However, trade of environmentally friendlier products as well as access to better technology embedded products through trade can also decrease the deterioration of environment by improving the efficient use of energy resources. Moreover, with an increase in national income, people are more likely to demand more and more environmentally friendlier products, process, and compliance standards. In the second group of literature, the main advantage of using input-output tables is that the entire economy is covered. As initial efforts, Lenzen (1998), Mongelli et al. (2006), and Pan et al. (2008) conduct their analysis to find emission embodied in trade utilizing country level input-output tables for Austria, Italy, and China, respectively. Recent studies such as Fan et al. (2019), Zhang et al. (2021), and Liu and Zhao (2021) significantly differ from the previous studies because they employ the value-added trade accounting method. Among these studies, some of them find that innovation, capital, and knowledge transfers/spillovers through participations into GVC can be seen as important tools to cope with the environmental hazardous. Contrariwise, Dinda and Coondoo (2006) and Wang et al. (2019) find the negative association between trade and air quality. Yanikkaya et al. (forthcoming) also analyze the association between forward GVC participation and greenhouse gas emission intensity (GHG) using the same dataset we utilize in this study but in a unilateral framework. They suggest that while the involvement of developed countries in GVC is more likely to raise their greenhouse emission intensity, the involvement of developing countries is more likely to improve the air quality owing to higher dependence

of renewable energy resources in these countries and higher environmental regulations in the international markets.

Therefore, there is a limited empirical evidence regarding on this subject, almost all other studies are descriptive ones (Fan et al., 2019; Fei et al., 2020; Zhang et al., 2021). Empirical studies analyzing the emissions through the input-output tables only focus on CO_2 emissions for specific countries and sectors (Meng et al., 2018; Guedidi and Baghdadi, 2020), and traces and calculates emissions only in forward linkages with unilateral dataset (Liu et al., 2020; Liu and Zhao, 2021) or fail to utilize the more recent value-added decomposition methodology provided by Wang et al. (2017) which decomposes production based on producer and user's perspectives.

Examining the emissions in trade rather than the emissions in production is vital to find actual values of emissions triggered by the countries. An exporting country generates emissions not only for domestic uses but also for imports. If an importing country had produced the tradable product on its own instead of importing it from abroad, it would have caused more emissions caused by switching to its own production. In this context, Pan et al. (2008) claim that even though developed economies assert reduction of their emissions, they actually switch their production places in mainly developing countries like China. Jakob et al. (2021) also argue that responsibility of emission does not solely belong to producers or consumers, but it should be shared by considering the whole value chain. Therefore, our main contributions to the literature are calculating greenhouse gas emissions with such a large bilateral dataset at the sectoral level by using the advanced value-added decomposition methodology and providing evidence for both backward and forward linkages. It is necessary to state that it is possible to calculate domestically released emissions and other relevant variables embodied in exports of the suppliers by the usual life-cycle assessments based on the forward linkages. This can provide valuable response to the question that who are mostly accounted for the emissions. Since countries have thus significant impacts on other countries' domestic productions by their demands from them and how import demand affects emissions and other relevant variables are also important research questions. Thus, the responsibility for emissions is not only related with production and exports from the supplier side but also equally related with the imports and consumption from the demander side.

In the first step, we calculate greenhouse gas emissions of sectors embedded in both backward and forward linkages by utilizing country and sectoral heterogeneities in our sample. We primarily present these statistics graphically in network visualization to reveal the

interactions of countries regarding greenhouse gas transmission so that we can detect the level of responsibility of country and problematic transactions. In the second step, we estimate the determinants of emissions in exports or forward participation by controlling both several sectoral and country level variables with a separate section devoted to the Middle East and North Africa (MENA) region.

Our network visualization below illustrates that developed countries appear to be as not only GHG producers but also GHG outsources because their productions mainly depend on major production/trade hubs of developing countries like China. While imports of developed countries, 67% of total world imports, are responsible for the 66% of total emissions in total imports, exports of developed countries, 66% of total world exports, are responsible for the 32% of total emissions in total exports, which firmly indicate the existence of emissions outsource in terms of developed countries. At the same time, China, the USA, Germany, Japan, and Russia are the top five emitters of greenhouse gas emission flows in the world. Especially, greenhouse gas emissions are highly embedded in trade with(in) China, the USA, and Russia. When we look at manufacturing and service sectors separately, while we can claim that GHG emissions embedded in transaction of manufacturing products follow similar pattern with overall sectors, trade in service products with the USA appears as a major threat to air quality, thereby climate change. Our empirical results on the full sample suggest that capital stock is positively, and renewable energy consumption is negatively associated with GHG emissions embedded in GVCs. We also observe a strong evidence for the environmental Kuznets curve hypothesis. Moreover, higher income and financialization seem to be elevate environmental degradation whereas trade agreements appear to be as environmental protective factors. These results obtained from full sample is generally similar to the results we obtained from six main aggregate sector groups and income level of trading partners but considerably varies for the MENA region.

The organization of the manuscript as follows. The next section explains data and methodology we employ. The third section presents the estimation results and final section concludes the manuscript.

2. Data and Methodology

Data

We employ both backward and forward linkages of sectors based on the global multi-regional input-output tables provided by the EORA (Lenzen et al., 2012, 2013), which cover 25 sectors[4] from 186 countries over the years from 1990 to 2015. We utilize total emissions of Kyoto greenhouse gases (GHG) excluding land use, land use change and forestry CO2-e (Gg). GHGs cover carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), per-fluorocarbons (PFCs) and sulphur hexafluoride (SF_6). We first calculate the emissions embedded in global value chain parts by utilizing the value-added trade accounting methodology of Wang et al. (2017) so that we can track the greenhouse gas emissions of individual sectors through the global production networks. We then follow the same calculation procedure to calculate the value added embedded in global value chain so that we can measure the greenhouse gas emission intensity by dividing emission to value added.

The sectoral variables such as value-added growth, capital intensity, and renewable energy consumption are taken from the same database, EORA. To calculate capital stock, we employ perpetual inventory method on gross fixed capital formation. The initial capital stock information is taken from IMF (2015) and sector specific depreciation rates are taken from the methodology notes of WIOD database (Erumban et al., 2012). To express capital stock intensity, we then divide capital stock by labor compensation. Renewable energy sources are hydroelectric; geothermal; wind, solar, tide and wave; and biomass and waste electricity (Nonrenewable electricity resources are natural gas, coal, petroleum, and nuclear power). We calculate the share of renewable energy resources out of all energy resources which sectors utilized.

The country level variables such as real GDP per capita, GDP deflator, resource rents (natural gas, oil, and coal), broad money are taken from the World Bank. While resource rents as a share of GDP are used as a proxy for the resource abundancy, broad money as a share of GDP shows financial development of countries. Human capital index is taken from Penn World

[4] The sectors are agriculture fishing; mining and quarrying; food & beverages; textiles and wearing apparel wood and paper; petroleum, chemical and non-metallic mineral products; metal products; electrical and; machinery; transport equipment; other manufacturing; recycling; electricity, gas and water; construction; maintenance and repair; wholesale trade; retail trade; hotels and restaurants transport; post and telecommunications; financial intermediation and business activities; public administration education, health and other services; private households; and others. See Table A1 in the Appendix part for countries in our sample.

Table (PWT). Gravity measures such as being signatory of WTO-FTA and being members of GATT are taken from Institute for Research on the International Economy (Centre d'Etudes Prospectives et d'Informations Internationales - CEPII).

Table 1 presents the summary statistics of variables. The first notable thing is that while GHG emission intensity in backward linkages is similar for developed and developing countries, greenhouse gas emission intensity in forward linkages of developing countries is significantly higher from than that of developed countries ($p=0.001$). On the other hand, the share of renewable energy consumption of developing countries is twice that of developed countries. The detailed summary statistics regarding greenhouse gas emission intensity of six main sectors are given in Table A2 in the Appendix.

To understand the bilateral country relationship in terms of greenhouse gas emission intensity, we utilize network graphs. Figure 1 indicates the GHG gas emissions of four main country groupings based on income level (high-, upper middle-, lower middle-, and low-income countries) according to our calculations. Thick edges between the countries illustrate higher GHG emissions embedded in trade of country pairs and vice versa. In Figure 1, we notice that GHG emissions embedded in trade flows from low-income countries to high-income countries as well as among high-income countries are quite higher than the flows from any other trade partners. Note that imports of developed countries consist of a 65% of emissions in total imports. The same trend is observable for manufacturing industries (see, Figure 2). In fact, these results are quite expected when the fragmented production in global value chains is considered. Especially in the last three decades, many developed countries switch their manufacturing production places in mainly developing countries to take advantage of cheap labor force and resources in these countries. In other words, developed countries outsource their GHG emissions elsewhere. For service industries, we also detect substantial amount of greenhouses gas emissions embedded in trade flows in high income countries themselves, which also provides an evidence for rapid servicification and deindustrialization period of developed countries (see, Figure 3).

Table 1: Summary Statistics

	Total		Developed		Developing		MENA	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Emission Intensity_backward	52.62	634.04	50.85	610.48	52.93	638.17	50.91	612.51
Emission Intensity_forward	251.87	46,956.00	7.51	744.15	295.56	50,979.57	7.82	426.76
Value-added growth	0.00	0.03	0.00	0.01	0.00	0.04	0.00	0.01
Value-added growth_partner	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.02
Capital stock intensity	3.94	236.07	0.01	0.01	4.65	256.30	0.01	0.01
Capital stock intensity_partner	0.09	1.10	0.09	1.10	0.09	1.10	0.09	1.08
Renewable energy	0.22	0.29	0.12	0.20	0.24	0.30	0.11	0.19
Renewable energy_partner	0.24	0.26	0.24	0.26	0.24	0.26	0.24	0.26
GDP per capita	10.54	16.66	45.88	15.53	4.23	4.58	16.96	19.81
GDP per capita_partner	10.47	16.54	10.20	16.25	10.52	16.59	10.57	16.65
Resource Rents	0.05	0.10	0.06	0.13	0.05	0.10	0.19	0.17
Resource Rents_partner	0.05	0.10	0.05	0.10	0.05	0.10	0.05	0.10
Human Capital Index	2.30	0.69	3.16	0.45	2.15	0.60	2.15	0.53
Human Capital Index_partner	2.31	0.69	2.31	0.68	2.31	0.69	2.33	0.69
Broad Money	0.50	0.40	0.96	0.60	0.42	0.28	0.65	0.25
Broad Money_partner	0.51	0.40	0.50	0.39	0.51	0.40	0.51	0.40
FTA_WTO	0.07	0.25	0.10	0.30	0.06	0.25	0.07	0.26
GATT	0.85	0.36	0.99	0.09	0.82	0.38	0.64	0.48
GATT_partner	0.85	0.36	0.85	0.36	0.85	0.36	0.86	0.35
# of Obs.	7,115,878		1,079,178		6,036,700		854,975	

Notes: See Table A1 in the Appendix for the country groupings. Greenhouse gas emission intensities are the ratios of greenhouse gas emissions (kg) to real value added in GVC transactions. Capital stock and GDP per capita are in thousands. Countries in the MENA region are Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, the UAE, and Yemen.

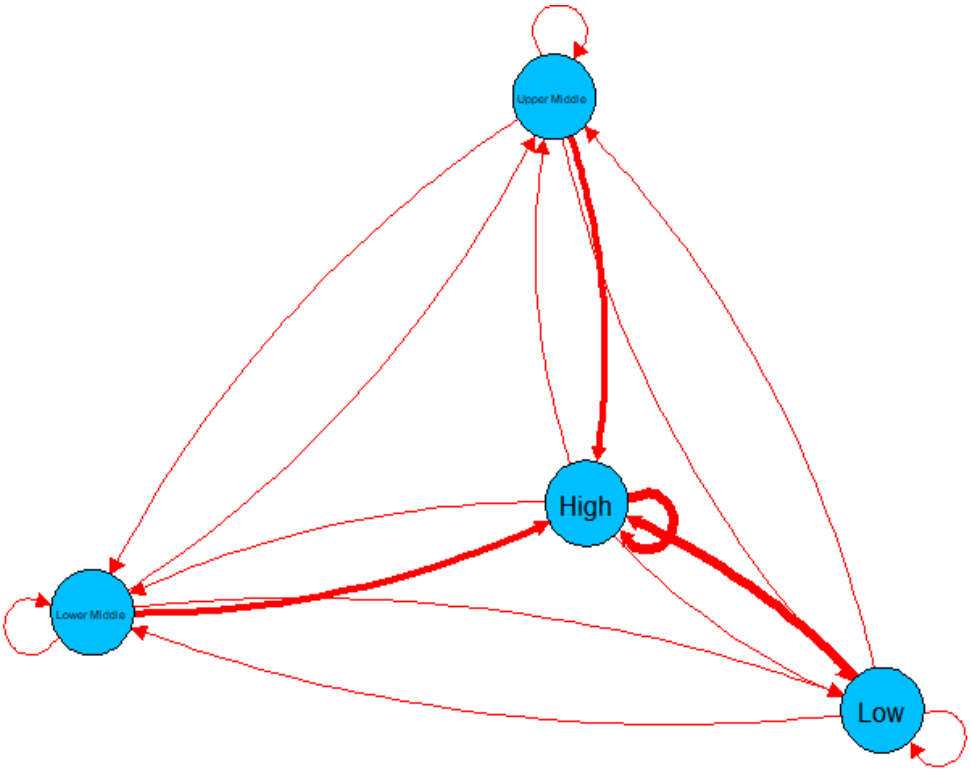

Figure 1: Network Diagram of Polluters by Country Groupings (based on income categories and the average of the period 1990-2015)

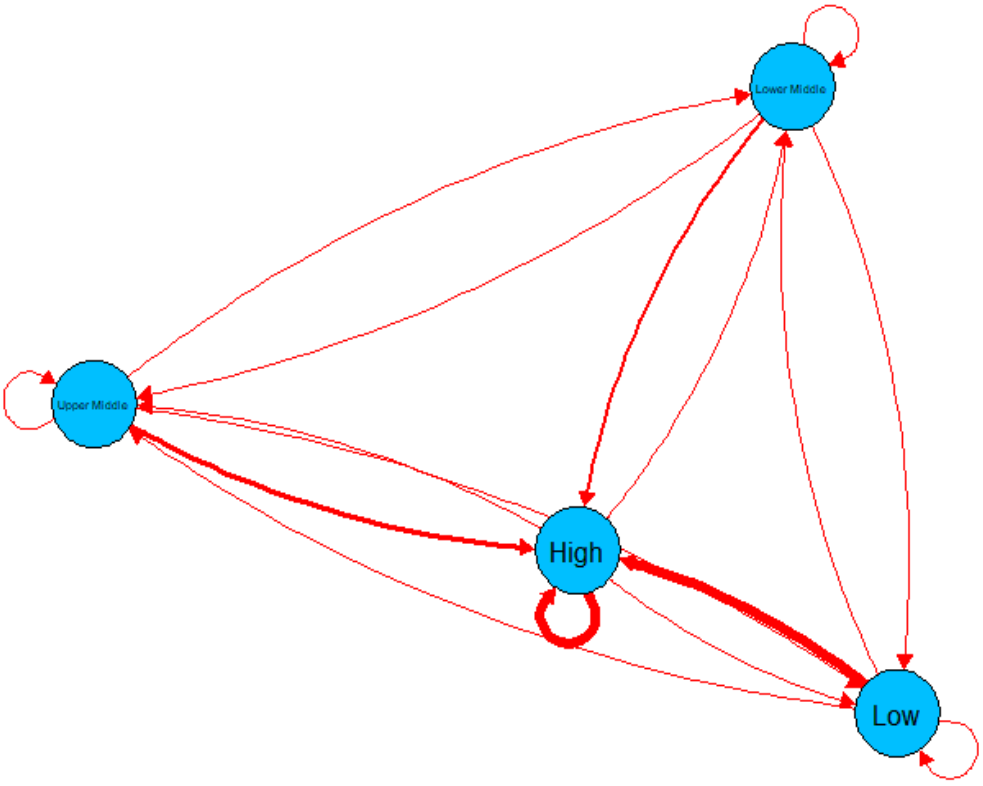

Figure 2: Network Diagram of Polluters by Country Groupings, Manufacturing

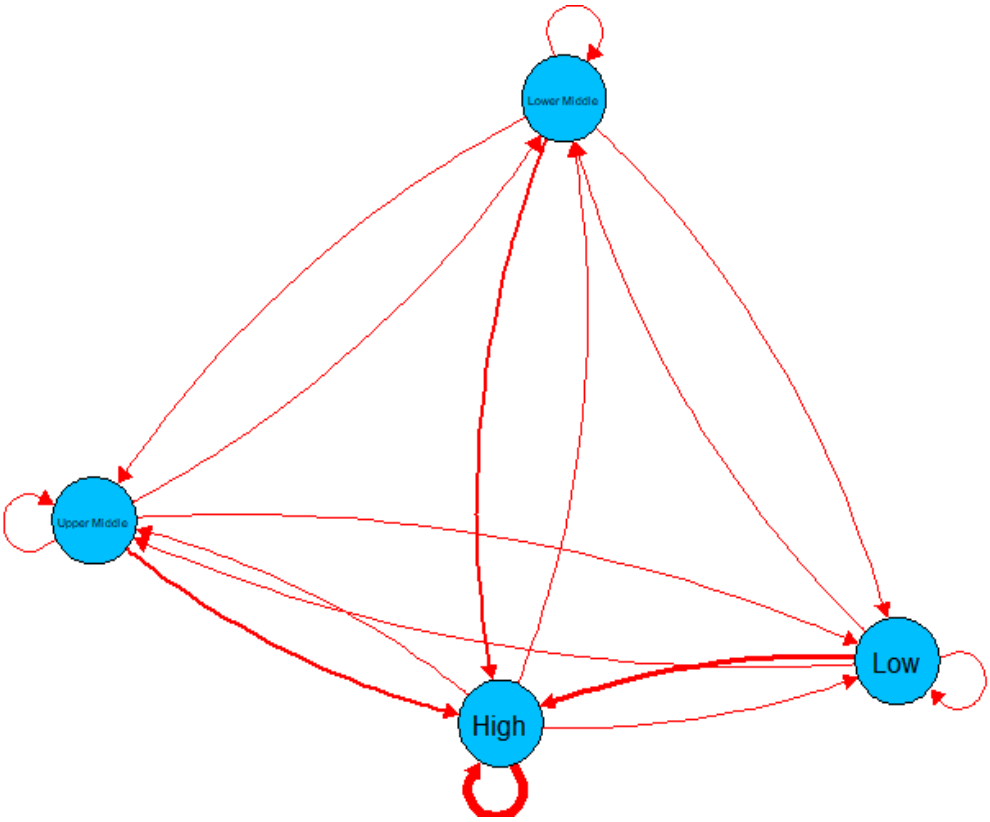

Figure 3: Network Diagram of Polluters by Country Groupings, Service

We also present similar graphs for the GHG gas emissions of top 5 emitters and the rest of the world in Figures A2-A4 in the Appendix part for total sample, manufacturing, and service, respectively. It is important to note that these five countries constitute 40% of greenhouse gas emissions in the world. We notice that China (responsible for 12% of total emission), the USA (12%), Germany (5%), Japan (5%), and Russia (5%) are mainly responsible for increasing greenhouse gas emissions. This proves the higher centrality of these countries in terms of production and thereby trade as well as it provides a real target for environmental policy regulators to focus on. Obviously, trade with these five countries are the most important transactions which needs to be carefully regulated as well as trade among China-the USA and China-Japan deserves special attention. The detailed country positions are illustrated in the Figure A1 in the Appendix.

We also present the graphs of two main sectoral groups; these are manufacturing and services. For manufacturing industries, we can observe nearly the same pattern with overall sample. For service sectors, trade with the USA is one embedded the most GHG emissions which urgently calls governments to decarbonize their economies.

Methodology

We specify the equation (1) below by following mainly the model introduced in Liu and Zhao (2021), to analyze the producer and consumer related determinants of greenhouse gas emissions embedded in GVCs. Our main focus is on global value chains because product fragmentation is only possible with an intense usage of transportation system. This inevitably threatens air quality and contributes the climate change.

$$GHG_{c,s,p,t} = \beta_0 + \beta_1 S^d_{c,s,t} + \beta_2 S^f_{p,t} + \beta_3 C^d_{c,t} + \beta_4 C^f_{p,t} + \beta_5 T_t + \varepsilon_{c,s,p,t} \quad (1)$$

where c, s, p and t stand for home country, sectors, partner country, and year, respectively. $GHG_{c,s,p,t}$ stands for greenhouse gas emission intensity embedded in forward GVCs.[5] $S^d_{c,s,t}$ represents the vector of sectoral control variables such as value-added growth, capital intensity, and renewable energy consumption (Chiu and Chang, 2009; de Souza et al., 2018) of home countries and $S^f_{p,t}$ stands for the same variables at country level for partner countries. $C^d_{c,t}$ and $C^f_{p,t}$ signify the vector of country level control variables such as real GDP per capita, square term of real GDP per capita (Grossman and Krueger, 1991; Holtz-Eakin and Selden, 1995; Wang et al., 2019), resource rent as a share of GDP, human capital index, and broad money as a share of GDP of both home and partner countries, respectively. We also control the gravity measures such as being signatory of WTO-FTA and being members of GATT (Guedidi and Baghdadi, 2020). T_t stands for time dummies. We take the natural logarithm of greenhouse gas emission intensity, capital intensity, and GDP per capita.

The model is estimated by utilizing the Two-Way Fixed Effects (TWFE) estimation procedures to investigate the determinants of greenhouse gas emission intensity.[6]

[5] We also estimate emissions in backward linkages, but the sign of estimates is just the opposite direction of what we have found for forward linkages as expected. Therefore, we provide only the results of forward linkages in here, but the results of backward linkage are also available upon request.

[6] Since we estimate a kind of export supply function, the model we use here can be considered to have some endogeneity concerns. To the address the endogeneity concerns which may arise, we also run our model by excluding renewable energy resources from the model. The results are similar with what we have estimated in the benchmark equations. As a second robustness check, we also include institutional quality index of countries (these statistics are available after the year 1995 and taken from the World Bank Development Indicators) in our model and rerun the regressions. Again, the results are very similar, and they are available upon request.

3. Results

This section represents the results of determinants of GHG emissions embedded in forward global value chains considering both sectoral and country level characteristics in a gravity like framework and utilizing the sectoral heterogeneities. Greenhouse gas emissions can be higher because of the rise in production, that is scale effect or increase in production of higher polluting industries, that is the composition effect (World Development Report, 2020). Although higher production process and trade lead to environmental degradation, trade of environmentally friendly goods, usage of clean and renewable energy resources, and technological enhancement making the process environmentally friendlier may slow down the hazardous impacts of production and trade activities. Since environmental repercussion of trade activities may differ depending on the development level of countries, we also consider country level heterogeneity considering the income levels of countries (see, Table A1 in the Appendix) in our sample thanks to the large coverage of the EORA database.

Table 2 presents the results for greenhouse gas emission intensity embedded in GVCs, that is transaction of intermediates in global trade. The aggregate results (at the column 1) suggest that while growth in value added does not have any significant effect on emission intensity, an increase in capital stock of exporter country is more likely to raise emission intensity embedded in forward trade flows. The share of renewable energy resources for exporters appears to be as one of the emissions decreasing factors.

When we consider country level variables, we observe an evidence for the Kuznets Curve hypothesis, that is greenhouse gas emission increases when GDP per capita rise until specific point of GDP per capita, but then it declines. While higher resource rents for exporter countries are more likely to result in lower GHG emissions, financial development levels of exporters are positively associated with emission intensity as we expect. Having free trade agreements with trading partners and being a GATT member are attributed to lower level of greenhouse gas emission intensity. This may be related to the higher environmental concerns in the world and thereby the new chapters introduced into the negotiations among trading partners. Notice that emissions embedded in forward linkages are mainly related to characteristics and behaviors of the exporters, that is the producers. The coefficients of almost all variables for importer country have in opposite signs with those of exporter country.

When we repeat our analysis by considering income level of trading partners (columns 2 to 5 of Table 2), we notice that these results are quite parallel with the main results regardless

of income levels of countries with several differences. One difference is the positive relationship between renewable energy usage of developed nations and their emissions if they trade with developing countries. While we expect that this clean energy resources do not negatively affect air quality, different types of utilizations from this resource can produce different outcomes for countries. Therefore, we can assert that the usage of any energy resources should be carefully monitored in all economies. The second one appears in the columns (2) and (3). We observe a U shape pattern between income level of economies and emission intensity for developed countries as opposed to the standard shape of Kuznets Curve. The third is that resource rents for exporter country are negatively correlated with emissions embedded in exports of developed nations whereas they are positively associated with the emissions embedded in exports of developing countries. Overall, we can claim that sectors which highly involve in GVC part of international trade should be particularly careful about their production process given the significant results for capital intensity and share of renewable energy consumption. Specifically, they should switch towards greener capital investment and minimize their usage of nonrenewable energy consumption.

Table 3 and Table 4 present the estimation results for manufacturing and services samples (see, the footnote 4 to see the coverage of these main sectors). For manufacturing industries in Table 3, all determinants which are significant in the benchmark analysis are generally significant in this sub-sample, too. It is noteworthy to mention that the relationship between the income level, resource rents, human capital level of exporter country and their emissions level embedded in forward linkages follow different patterns depending on level of income of exporters. For instance, while resource rents are emission reducing factor for developed countries, it is emission inducing factor for developing markets. Therefore, we can assert that governments in emerging economies should particularly monitor investment decisions of sectors and give incentives sectors to lead them towards sustainable production.

For service sectors in Table 4, we observe the similar relationship between right-hand side variables and greenhouse gas emission intensity embedded in GVCs. While capital stock, GDP per capita, and financial development are positively associated with the emission intensity, use of renewable energy resources, resource rents, having free trade agreements and being a signatory of GATT significantly reduce the emission intensity. Even though service sectors are not among the major emitters, given these results, apparently, these sectors also benefit from implementing measures to address environmental issues.

Table 2: Greenhouse Gas Emission Intensity Embedded in GVCs by Country Groupings

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
	(1)	(2)	(3)	(4)	(5)
Value-added growth	-0.000	-0.134	-0.023	-0.000	-0.016
	(0.011)	(0.094)	(0.019)	(0.011)	(0.035)
Value-added growth_partner	-0.007	-0.124	-0.008*	0.008	0.078
	(0.006)	(0.183)	(0.004)	(0.013)	(0.158)
Capital stock intensity	0.060***	0.055***	0.050***	0.054***	0.059***
	(0.001)	(0.007)	(0.002)	(0.001)	(0.004)
Capital stock intensity_partner	-0.001*	-0.005	-0.002***	-0.002***	0.007
	(0.001)	(0.011)	(0.001)	(0.001)	(0.007)
Renewable energy	-0.043***	0.016	0.043***	-0.042***	-0.038***
	(0.002)	(0.023)	(0.006)	(0.002)	(0.006)
Renewable energy_partner	0.011***	0.039*	0.006**	0.006***	0.011
	(0.002)	(0.022)	(0.003)	(0.002)	(0.017)
GDP per capita	0.687***	-2.105***	-2.316***	1.025***	1.010***
	(0.009)	(0.390)	(0.107)	(0.014)	(0.043)
GDP per capita_sq	-0.058***	0.088***	0.097***	-0.083***	-0.081***
	(0.001)	(0.019)	(0.005)	(0.001)	(0.003)
GDP per capita_partner	-0.011	3.549***	-0.003	-0.006	2.376***
	(0.009)	(0.536)	(0.015)	(0.012)	(0.340)
GDP per capita sq_partner	-0.000	-0.176***	-0.001	-0.000	-0.117***
	(0.001)	(0.025)	(0.001)	(0.001)	(0.016)
Resource Rents	-0.022***	-0.519***	-0.516***	0.094***	0.104***
	(0.006)	(0.061)	(0.017)	(0.006)	(0.022)
Resource Rents_partner	0.018***	0.268***	-0.001	-0.005	0.205***
	(0.006)	(0.054)	(0.008)	(0.006)	(0.038)
Human Capital Index	0.003	0.282***	0.295***	-0.104***	-0.085***
	(0.004)	(0.019)	(0.004)	(0.005)	(0.017)
Human Capital Index_partner	-0.007*	0.015*	-0.009	-0.004	0.008
	(0.004)	(0.008)	(0.008)	(0.006)	(0.007)
Broad Money	0.058***	0.088***	0.086***	0.039***	0.040***
	(0.002)	(0.008)	(0.002)	(0.003)	(0.010)
Broad Money_partner	-0.005**	-0.030***	-0.017***	-0.011***	-0.027***
	(0.002)	(0.010)	(0.004)	(0.003)	(0.006)
FTA_WTO	-0.009***	-0.016**	0.008***	-0.014***	0.012**
	(0.002)	(0.007)	(0.002)	(0.002)	(0.005)
GATT	-0.030***	-0.096***	-0.109***	-0.024***	-0.023***
	(0.001)	(0.014)	(0.003)	(0.002)	(0.005)
GATT_partner	0.007***	-0.039***	0.011***	0.007***	-0.018***
	(0.001)	(0.013)	(0.002)	(0.001)	(0.007)
Constant	-1.144***	-5.861	13.276***	-2.230***	-14.297***
	(0.052)	(3.757)	(0.561)	(0.072)	(1.803)
# of Obs.	7,115,878	154,020	925,158	5,121,294	915,406
R-squared	0.880	0.584	0.698	0.896	0.836

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Greenhouse Gas Emission Intensity Embedded in GVCs by Country Groupings, Manufacturing

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
	(1)	(2)	(3)	(4)	(5)
Value-added growth	0.003	-0.202	-0.037	0.007	-0.081
	(0.006)	(0.170)	(0.033)	(0.006)	(0.065)
Value-added growth_partner	-0.000	-0.423*	-0.097	-0.003	0.100
	(0.011)	(0.223)	(0.072)	(0.010)	(0.238)
Capital stock intensity	0.036***	0.041***	0.041***	0.031***	0.027***
	(0.001)	(0.014)	(0.003)	(0.002)	(0.005)
Capital stock intensity_partner	-0.001	-0.011	-0.004***	-0.003***	0.010
	(0.001)	(0.020)	(0.001)	(0.001)	(0.013)
Renewable energy	-0.053***	0.018	0.010	-0.044***	-0.045***
	(0.003)	(0.033)	(0.008)	(0.003)	(0.010)
Renewable energy_partner	0.020***	0.018	0.007*	0.012***	0.011
	(0.003)	(0.033)	(0.004)	(0.004)	(0.026)
GDP per capita	0.904***	-2.355***	-2.453***	1.255***	1.402***
	(0.017)	(0.673)	(0.154)	(0.023)	(0.079)
GDP per capita_sq	-0.072***	0.093***	0.101***	-0.097***	-0.108***
	(0.001)	(0.033)	(0.008)	(0.002)	(0.005)
GDP per capita_partner	-0.020	3.504***	-0.007	-0.015	5.465***
	(0.015)	(0.935)	(0.026)	(0.021)	(0.669)
GDP per capita sq_partner	-0.001	-0.174***	-0.000	0.000	-0.272***
	(0.001)	(0.044)	(0.002)	(0.001)	(0.032)
Resource Rents	-0.050***	-0.723***	-0.582***	0.091***	0.094**
	(0.012)	(0.116)	(0.025)	(0.012)	(0.046)
Resource Rents_partner	0.054***	0.262***	0.002	0.009	0.464***
	(0.010)	(0.093)	(0.011)	(0.009)	(0.082)
Human Capital Index	-0.005	0.429***	0.376***	-0.133***	-0.154***
	(0.007)	(0.037)	(0.007)	(0.009)	(0.033)
Human Capital Index_partner	-0.012	0.018	-0.012	-0.005	0.029***
	(0.007)	(0.014)	(0.014)	(0.011)	(0.011)
Broad Money	0.051***	0.107***	0.111***	0.019***	0.009
	(0.003)	(0.010)	(0.003)	(0.005)	(0.017)
Broad Money_partner	-0.015***	-0.028*	-0.022***	-0.034***	-0.062***
	(0.004)	(0.017)	(0.006)	(0.005)	(0.012)
FTA_WTO	-0.012***	-0.024**	0.009***	-0.012***	-0.007
	(0.003)	(0.012)	(0.004)	(0.003)	(0.008)
GATT	-0.030***	-0.165***	-0.119***	-0.023***	-0.021**
	(0.003)	(0.030)	(0.006)	(0.003)	(0.009)
GATT_partner	0.015***	-0.051***	0.010***	0.018***	-0.056***
	(0.002)	(0.017)	(0.003)	(0.003)	(0.011)
Constant	-1.787***	-3.833	14.125***	-2.979***	-30.984***
	(0.091)	(6.430)	(0.791)	(0.125)	(3.558)
# of Obs.	2,549,104	54,855	329,637	1,836,421	328,191
R-squared	0.793	0.566	0.711	0.816	0.716

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Greenhouse Gas Emission Intensity Embedded in GVCs by Country Groupings, Services

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
	(1)	(2)	(3)	(4)	(5)
Value-added growth	0.008***	-0.074	-0.011	0.007***	-0.039
	(0.003)	(0.145)	(0.029)	(0.003)	(0.031)
Value-added growth_partner	-0.004	-0.091	-0.645	0.068	0.005
	(0.072)	(0.299)	(0.500)	(0.065)	(0.250)
Capital stock intensity	0.056***	0.121***	0.110***	0.045***	0.048***
	(0.001)	(0.012)	(0.004)	(0.001)	(0.003)
Capital stock intensity_partner	-0.000	0.011	-0.001	-0.001	0.009
	(0.001)	(0.016)	(0.001)	(0.001)	(0.008)
Renewable energy	-0.026***	0.095**	0.120***	-0.038***	-0.030***
	(0.002)	(0.040)	(0.010)	(0.002)	(0.007)
Renewable energy_partner	0.012***	0.053	0.006	0.007**	0.029
	(0.002)	(0.037)	(0.005)	(0.003)	(0.024)
GDP per capita	0.613***	-0.510	-1.323***	0.943***	0.874***
	(0.012)	(0.583)	(0.176)	(0.020)	(0.055)
GDP per capita_sq	-0.052***	0.014	0.050***	-0.077***	-0.072***
	(0.001)	(0.028)	(0.008)	(0.001)	(0.004)
GDP per capita_partner	-0.003	3.769***	-0.001	-0.003	2.251***
	(0.011)	(0.656)	(0.022)	(0.015)	(0.375)
GDP per capita sq_partner	-0.001	-0.189***	-0.001	-0.000	-0.112***
	(0.001)	(0.031)	(0.001)	(0.001)	(0.018)
Resource Rents	-0.018**	-0.322***	-0.400***	0.084***	0.099***
	(0.007)	(0.081)	(0.030)	(0.007)	(0.018)
Resource Rents_partner	0.015**	0.344***	-0.000	-0.009	0.223***
	(0.008)	(0.083)	(0.014)	(0.008)	(0.042)
Human Capital Index	0.010**	0.193***	0.245***	-0.082***	-0.037**
	(0.004)	(0.024)	(0.005)	(0.005)	(0.018)
Human Capital Index_partner	-0.007	0.013	-0.005	-0.004	0.007
	(0.005)	(0.013)	(0.011)	(0.007)	(0.009)
Broad Money	0.042***	0.042***	0.043***	0.032***	0.046***
	(0.003)	(0.013)	(0.004)	(0.004)	(0.013)
Broad Money_partner	-0.003	-0.028**	-0.018***	-0.010***	-0.021***
	(0.003)	(0.013)	(0.006)	(0.004)	(0.007)
FTA_WTO	-0.012***	-0.001	0.005	-0.017***	0.012
	(0.003)	(0.011)	(0.004)	(0.003)	(0.008)
GATT	-0.022***	-0.032*	-0.082***	-0.016***	-0.017***
	(0.002)	(0.018)	(0.005)	(0.002)	(0.006)
GATT_partner	0.008***	-0.036	0.015***	0.008***	-0.012
	(0.002)	(0.023)	(0.003)	(0.002)	(0.008)
Constant	-1.094***	-15.369***	8.019***	-2.125***	-13.361***
	(0.067)	(5.066)	(0.930)	(0.095)	(1.984)
# of Obs.	3,146,481	68,409	410,767	2,262,747	404,558
R-squared	0.863	0.416	0.480	0.889	0.836

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

For the other main sectors, these are agriculture and fishing, mining, construction and electricity, gas and water, we also conduct the same empirical exercises. The results are given in the Appendix (Tables A3-A7), but it is noteworthy to state the general results briefly. Almost all the significant determinants of GHG emissions are also statically significant and display the same signs in six sector groupings except for resource rents. While resource rents are positively correlated with the emissions embedded in GVCs part of mining sector, they are negatively associated with emission for all other sectors. Still, we observe that higher emission intensity level is attributed to higher capital intensity, higher income, higher human capital, better financialization as well as lower level of renewable energy consumption, resource rents, and a lack of any trade agreements. In this respect, enhancement in regulations and negotiations on consumption of renewable energy resources in all countries can play an important role for addressing air quality.

The MENA Region

It seems that the MENA region has comparable shares (%3) in both world imports and total emissions in total imports. However, its exports share (5%) is almost half of total emissions in total exports (9%). In consumption point of view, these statistics imply that similar to lower-income countries, the MENA region seems to be much less responsible for the GHG emissions. Table 5 presents the estimation results we separately conduct for the MENA region by considering six main sectoral aggregates. Unlike the full sample of countries, value added growth in own sectors or trading partners' sectors lead to lower emission intensity. However, there is strong evidence for environmental degradation in higher level of incomes and environmental improvements in much higher levels of income, which is the inverted U-shape depicted by the Kuznets Curve. This may be related that after a specific turning point, higher environmental awareness and demand for environmentally friendly products rise, transparent and well-defined legislative procedure start to apply. This is also hold for all the sectors in the MENA region. Higher resource rents and human capital are negatively related to the emission intensity embedded in GVC part in all sectors except for construction sector. Financial development and being GATT member are positively associated to emission intensity of all sectors. Therefore, we can claim that mutual negotiations with the MENA region with special chapters devoted to environmental effects of traded product should be further developed.

Table 5: Greenhouse Gas Emission Intensity Embedded in GVCs of the MENA Region by Sectors

	Total	**Manufacturing**	**Service**	**Agriculture & Fishing**	**Mining**	**Construction**	**EGW**
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Value-added growth	-0.050**	-0.092*	-0.030	0.023	0.030	-0.071	0.211
	(0.023)	(0.047)	(0.021)	(0.055)	(0.021)	(0.104)	(0.292)
Value-added growth_partner	-0.011***	-0.178	-0.516	0.120	0.215	-0.006***	0.209
	(0.004)	(0.144)	(0.395)	(0.083)	(0.287)	(0.001)	(0.883)
Capital stock intensity	0.030***	-0.028***	0.021***	0.006	0.092***	0.289***	0.748***
	(0.002)	(0.004)	(0.003)	(0.015)	(0.006)	(0.013)	(0.035)
Capital stock intensity_partner	-0.001	-0.003	0.001	0.000	-0.000	-0.002	-0.002
	(0.001)	(0.003)	(0.001)	(0.004)	(0.002)	(0.004)	(0.012)
Renewable energy	0.037***	0.109***	0.125***	0.000	-0.070***	0.335***	-0.147
	(0.006)	(0.016)	(0.005)	(0.006)	(0.005)	(0.020)	(0.114)
Renewable energy_partner	0.010**	0.030***	0.004	0.015	-0.003	-0.002	-0.096**
	(0.004)	(0.008)	(0.005)	(0.010)	(0.008)	(0.014)	(0.041)
GDP per capita	0.944***	1.186***	1.061***	1.092***	0.679***	0.227**	2.708***
	(0.053)	(0.119)	(0.045)	(0.180)	(0.062)	(0.091)	(0.458)
GDP per capita_sq	-0.052***	-0.065***	-0.059***	-0.062***	-0.037***	-0.017***	-0.151***
	(0.003)	(0.006)	(0.002)	(0.010)	(0.003)	(0.005)	(0.024)
GDP per capita_partner	-0.004	-0.011	0.006	-0.052	0.007	-0.035	0.036
	(0.021)	(0.045)	(0.019)	(0.059)	(0.031)	(0.059)	(0.172)
GDP per capita sq_partner	-0.001	-0.003	-0.001	0.001	-0.000	0.002	0.010
	(0.001)	(0.003)	(0.001)	(0.004)	(0.002)	(0.004)	(0.012)
Resource Rents	-0.107***	-0.174***	-0.087***	-0.145***	-0.092***	0.280***	-0.223**
	(0.010)	(0.022)	(0.009)	(0.022)	(0.011)	(0.033)	(0.093)
Resource Rents_partner	0.023	0.083***	0.011	0.024	-0.003	-0.038	-0.315***
	(0.014)	(0.032)	(0.014)	(0.026)	(0.019)	(0.034)	(0.106)
Human Capital Index	-0.001	-0.082***	-0.034***	0.019	0.009	0.258***	-0.152*
	(0.010)	(0.024)	(0.009)	(0.027)	(0.015)	(0.021)	(0.081)
Human Capital Index_partner	-0.011	-0.023	-0.008	-0.015	0.001	0.001	0.057
	(0.010)	(0.022)	(0.008)	(0.029)	(0.014)	(0.022)	(0.081)
Broad Money	0.107***	0.072***	0.078***	0.110***	0.075***	0.149***	0.349***
	(0.008)	(0.017)	(0.005)	(0.018)	(0.011)	(0.012)	(0.063)
Broad Money_partner	-0.004	-0.022**	0.005	-0.011	0.000	0.008	0.064
	(0.005)	(0.011)	(0.005)	(0.016)	(0.008)	(0.015)	(0.041)
FTA_WTO	0.008**	0.020**	0.005	-0.001	0.005	-0.034***	-0.027
	(0.004)	(0.008)	(0.004)	(0.006)	(0.004)	(0.007)	(0.036)
GATT	0.045***	0.053***	0.041***	0.046***	0.040***	-0.039***	0.091***
	(0.003)	(0.006)	(0.003)	(0.009)	(0.004)	(0.006)	(0.027)
GATT_partner	0.007**	0.020***	0.007**	0.011	-0.004	-0.002	-0.087***
	(0.003)	(0.007)	(0.003)	(0.008)	(0.004)	(0.010)	(0.024)
Constant	-3.842***	-4.516***	-4.451***	-4.263***	-3.286***	-1.435***	-11.459***
	(0.245)	(0.546)	(0.218)	(0.848)	(0.314)	(0.464)	(2.210)
# of Obs.	854,975	304,002	380,849	69,241	34,634	33,159	33,090
R-squared	0.860	0.691	0.735	0.787	0.942	0.912	0.854

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

While a rise in capital intensity in manufacturing sector is more likely to improve air quality, the opposite effect prevails for the other sectors. Contrary to common expectations about the negative effects of renewable energy consumption on greenhouse gas emissions of sectors, we find the positive association between renewable energy use and greenhouse gas emission intensity of manufacturing, services, and construction sectors. This may be related to an increase of production of manufacturing, services, construction products as a result of large scale of deployment of energy resources. As a matter of fact, a higher share of renewable energy usage reduces only the pace of emission surge, because emissions in the air increase as a result of the heat arising from the use of any energy source. Furthermore, one of the renewable energy sources, hydropower, is generally subjected to debate because of its potential ecological effect. In other words, renewable energy consumption seems to raise emissions for mining and electricity, gas and water sector in the region. Therefore, this specific finding to the MENA region should be carefully evaluated and policy makers should take necessary actions regarding this concern.

4. Concluding Remarks

We calculate greenhouse gas emissions embedded in GVCs to assess the core responsibility of emissions and to understand the determinants of emission intensity utilizing the EORA database covering 186 countries and 26 sectors over 1990-2015. Our network graphs suggest that the environmental damage instigated by developed countries to the environment is not only caused by their own production, but also their consumption or intermediate products demand from abroad, that is actually outsourcing a huge amount of their potential climate pollution to the developing economies. Moreover, in terms of individual countries, China, the USA, Germany, Japan, and Russia have the huge chunk of responsibility for the GHG emissions in global value chains. While this picture is mainly similar for manufacturing products, the USA appears to be as a top polluter in services. For the MENA countries, we observe relatively lower greenhouse gas emission intensity compared to other country groupings.

Our empirical findings suggest that some sector specific characteristics are quite important to combat with the environmental degradation. While higher capital stock seems to raise environmental degradation, higher renewable energy shares are negatively related to GHG emission embedded in GVCs. Even if this result is generally true regardless of income level of countries and sectors, there are also some exceptions. Given these findings, investment decision and energy consumption process of sectors play a curial role to precisely understand the true effect of these two measures. Apart from the sector level variables, country level variables such

as resource rents and gravity measures such as having signatory of GATT also stand as significant factors to successfully fight against climate change whereas higher income levels and deeper financialization seem to be alerting factors.

Our empirical results clearly reveal the requirement of country/sectors specific investigation of these measures to propose more precise policies and ultimately decouple economic growth from environmental hazards. For instance, further development of investment and energy consumption decisions which are in line with the global environmental standard should be encouraged, whereas the production and trading activities of top emitters should be highly regulated and global environmental standards should be strictly enforced. In general, national and international environmental conservation policies such as binding laws and regulations and strong financial incentives for emissions reducing and energy efficient environmental projects needed to be further developed. Specifically, for the MENA region, monitoring the environmental responses of trading partners and implementing obligatory regulations in coordination with each other can help to reach greener economic growth. We can further argue that boosting usage of renewable resources, pricing environmental damage in the form of carbon taxes, and setting low carbon standards can be seen effective tools to fight with pollutants as well as to sustain greener production.

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Appendix

Table A1. The Country List (EORA)

High-income		Upper middle-income		Lower middle-income			Low-income	
Andorra	New Zealand	Antigua	Trinidad and Tobago	Albania	Guatemala	Syria	Afghanistan	Maldives
Aruba	Norway	Bahrain	Uruguay	Algeria	Iran	TFYR Macedonia	Bangladesh	Mali
Australia	Qatar	Barbados	Venezuela	Angola	Jamaica	Tajikistan	Benin	Mauritania
Austria	San Marino	Belarus		Argentina	Jordan	Thailand	Bhutan	Mozambique
Bahamas	Singapore	Brazil		Armenia	Kazakhstan	Tunisia	Burkina Faso	Myanmar
Belgium	Spain	Estonia		Azerbaijan	Kyrgyzstan	Turkey	Burundi	Nepal
Bermuda	Sweden	Gabon		Belize	Lebanon	Turkmenistan	Cambodia	Niger
Brunei	Switzerland	Greece		Bolivia	Malaysia	Ukraine	Central African Republic	Nigeria
Canada	Taiwan	Hungary		Bosnia and Herzegovina	Mauritius	Uzbekistan	Chad	Pakistan
Cayman Islands	UAE	Iraq		Botswana	Moldova	Vanuatu	China	Rwanda
Cyprus	UK	Latvia		Bulgaria	Mongolia	Yemen	DR Congo	Sao Tome and Principe
Denmark	USA	Libya		Cameroon	Montenegro	Zimbabwe	Egypt	Sierra Leone
Finland		Lithuania		Cape Verde	Morocco		Eritrea	Somalia
France		Macao SAR		Chile	Namibia		Ethiopia	South Sudan
French Polynesia		Malta		Colombia	Nicaragua		Gambia	Sri Lanka
Germany		Mexico		Congo	North Korea		Ghana	Sudan
Greenland		Netherlands Antilles		Costa Rica	Panama		Guinea	Tanzania
Hong Kong		New Caledonia		Cote dIvoire	Papua New Guinea		Guyana	Togo
Iceland		Oman		Croatia	Paraguay		Haiti	Uganda
Ireland		Portugal		Cuba	Peru		Honduras	Viet Nam
Israel		Russia		Czech Republic	Philippines		India	Zambia
Italy		Saudi Arabia		Djibouti	Poland		Indonesia	
Japan		Seychelles		Dominican Republic	Romania		Kenya	
Kuwait		Slovenia		Ecuador	Samoa		Laos	
Liechtenstein		South Africa		El Salvador	Senegal		Lesotho	
Luxembourg		South Korea		Fiji	Serbia		Liberia	
Monaco		Suriname		Gaza Strip	Slovakia		Madagascar	
Netherlands		Gabon		Georgia	Swaziland		Malawi	

Notes: Income classification is based on the country's 1990 income level (World Bank, 2020). Developed countries are high-income countries whereas developing countries consist of upper middle-, lower middle-, and low-income countries.

Table A2. Summary Statistics of GHG Emission Intensity by Sectors

	Total		Developed		Developing		MENA	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Total								
Emission Intensity_backward	52.62	634.04	50.85	610.48	52.93	638.17	50.91	612.51
Emission Intensity_forward	251.87	46,956.00	7.51	744.15	295.56	50,979.57	7.82	426.76
Manufacturing								
Emission Intensity_backward	52.57	633.21	51.33	610.66	52.79	637.16	50.73	608.14
Emission Intensity_forward	206.73	54,273.82	1.88	155.76	243.11	58,897.02	8.84	322.24
Service								
Emission Intensity_backward	52.37	631.58	49.68	599.65	52.85	637.15	50.54	610.49
Emission Intensity_forward	285.23	50,772.07	14.56	1,106.90	333.85	55,142.23	5.50	567.51
Agriculture & Fishing								
Emission Intensity_backward	53.09	638.80	52.30	624.49	53.24	641.33	51.67	619.99
Emission Intensity_forward	1.95	91.02	1.75	113.39	1.99	86.38	2.59	137.88
Mining								
Emission Intensity_backward	53.82	646.09	53.33	634.98	53.91	648.03	51.83	626.69
Emission Intensity_forward	0.74	3.06	0.42	1.54	0.80	3.25	0.22	0.49
Construction								
Emission Intensity_backward	51.97	626.97	49.56	594.76	52.40	632.64	50.80	609.72
Emission Intensity_forward	1.12	9.78	0.68	3.21	1.20	10.54	2.31	25.39
EGW								
Emission Intensity_backward	54.44	655.33	55.98	690.76	54.17	648.90	54.38	647.96
Emission Intensity_forward	1,303.29	15,714.64	4.95	12.84	1,531.63	17,030.37	49.57	50.32

Notes: See Table A1 in the Appendix for the country groupings and the footnote 4 to see the coverage of these main sectors. Greenhouse gas emission intensities are the ratios of greenhouse gas emissions (kg) to real value added in GVC transactions. Countries in the MENA region are Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, the UAE, and Yemen.

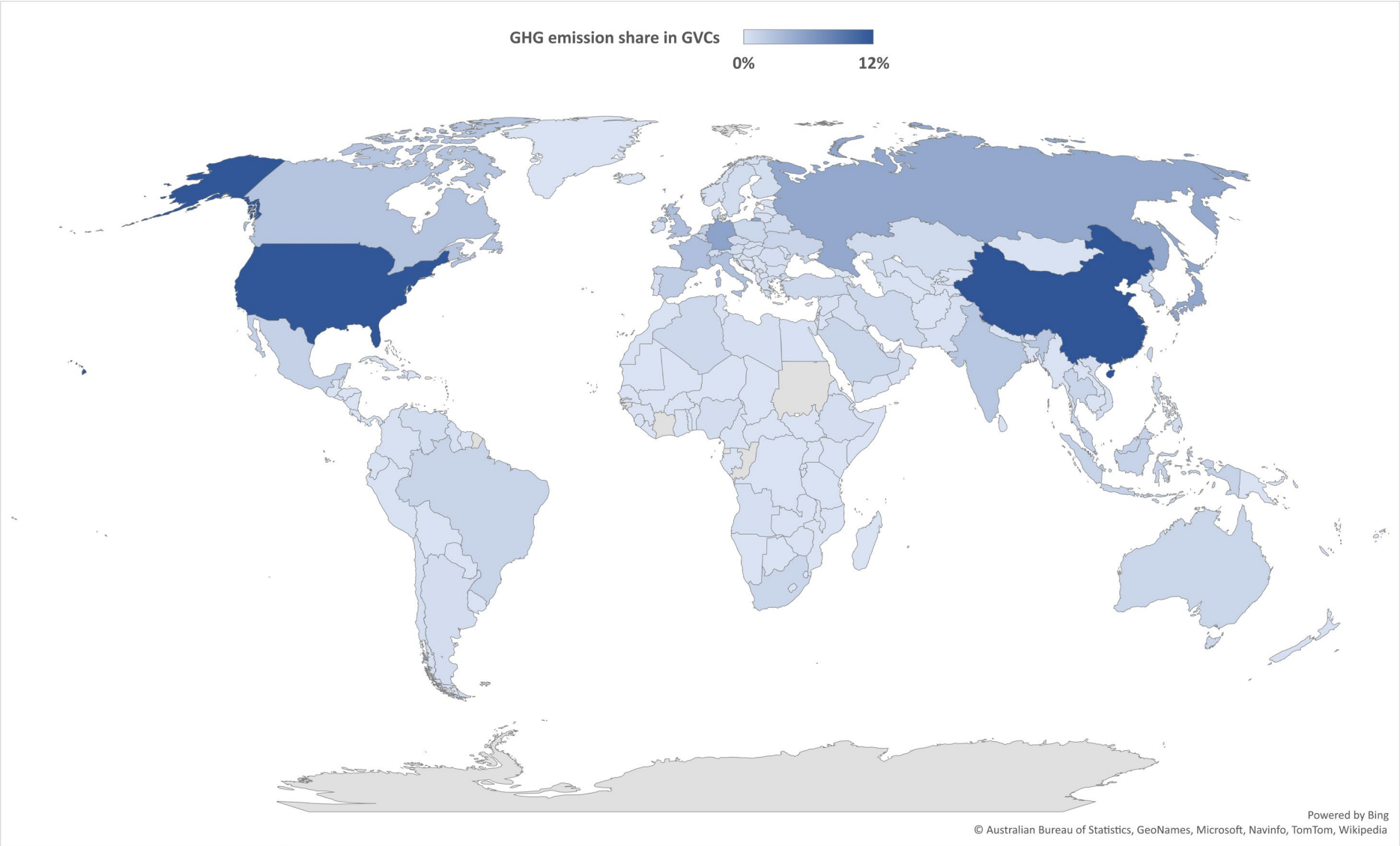

Figure A1. The Share of Greenhouse Gas Emissions Embedded in GVC by Countries

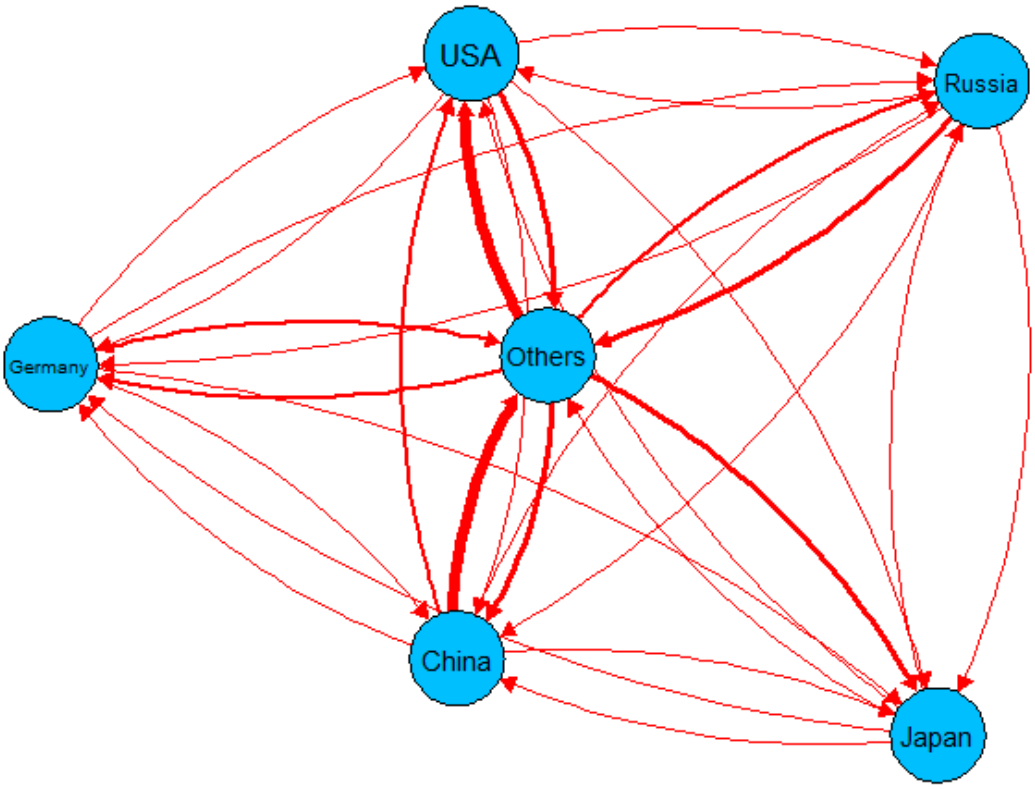

Figure A2. Network Diagram of Top Polluters, All Sectors (the average of the period 1990-2015)

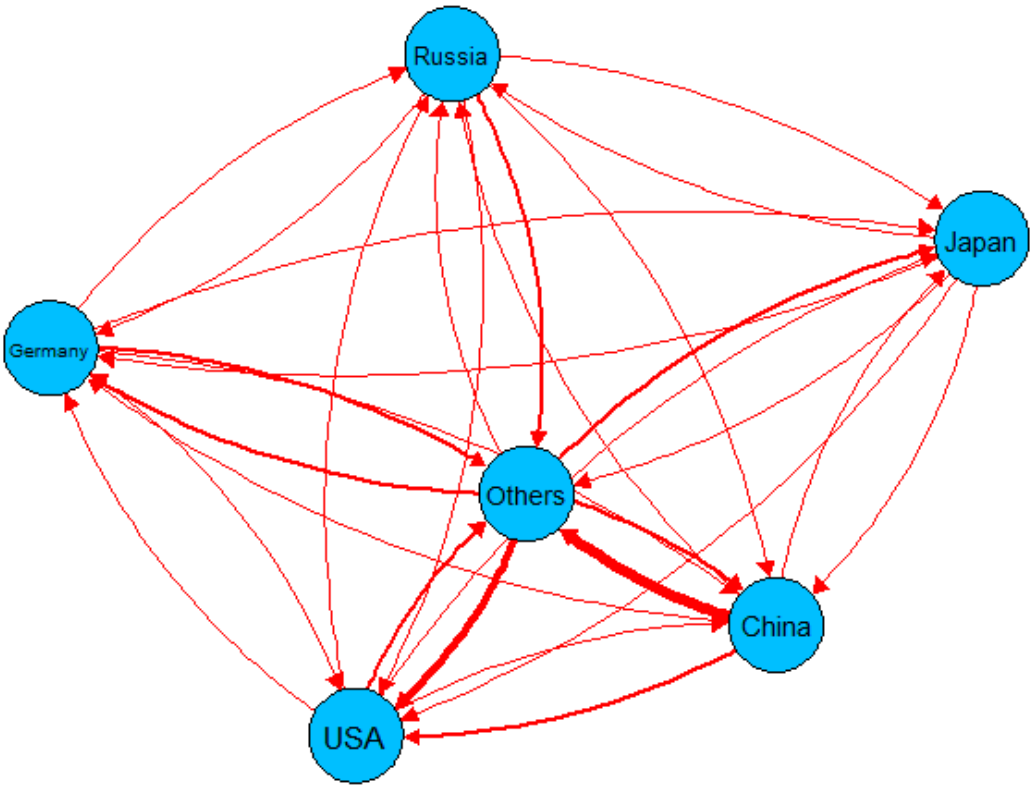

Figure A3. Network Diagram of Top Polluters, Manufacturing

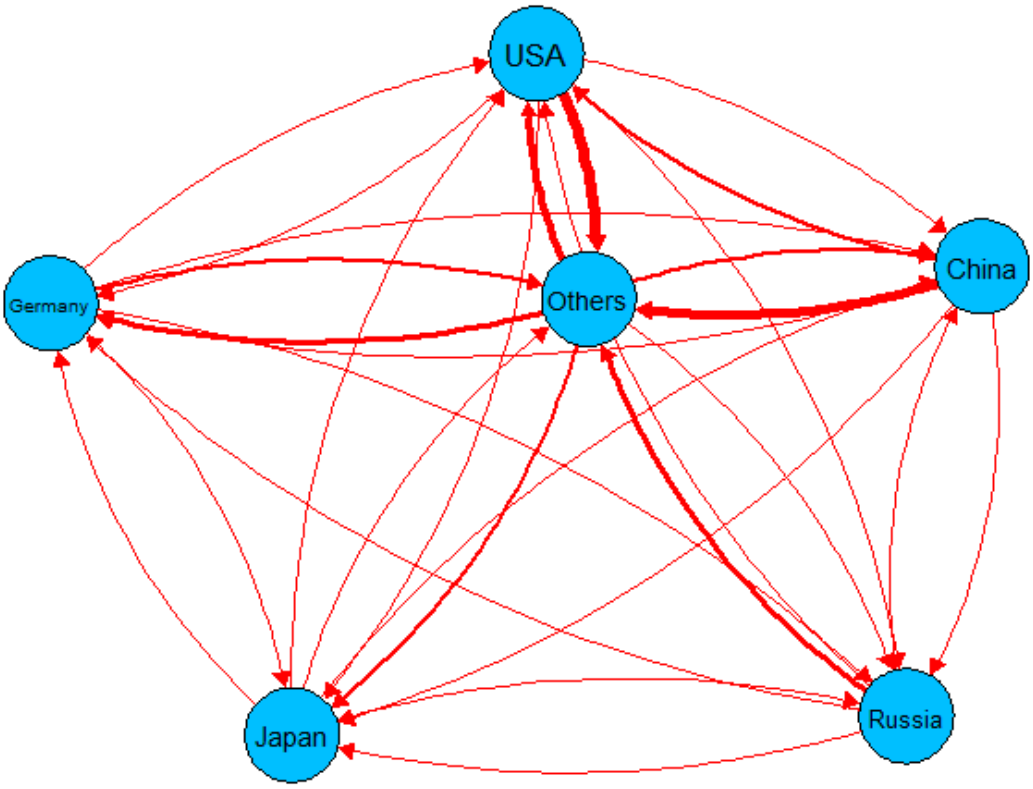

Figure A4. Network Diagram of Top Polluters, Service

Table A3. Greenhouse Gas Emission Intensity Embedded in GVC by Country Groupings, Agriculture & Fishing

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
Variables	(1)	(2)	(3)	(4)	(5)
Value-added growth	-0.004	-0.250	-0.030	-0.003	-0.078
	(0.011)	(0.239)	(0.048)	(0.010)	(0.089)
Value-added growth_partner	-0.081	-0.354	0.305**	-0.144	-0.233
	(0.109)	(0.253)	(0.119)	(0.127)	(0.245)
Capital stock intensity	0.001	0.089*	0.096***	-0.004**	-0.006
	(0.002)	(0.052)	(0.011)	(0.002)	(0.005)
Capital stock intensity_partner	-0.001	-0.048	-0.004	-0.003	0.013
	(0.002)	(0.048)	(0.003)	(0.002)	(0.019)
Renewable energy	-0.060***	-0.065	0.002	-0.053***	-0.058***
	(0.003)	(0.057)	(0.008)	(0.003)	(0.011)
Renewable energy_partner	0.017***	0.001	0.016*	0.009*	0.006
	(0.005)	(0.068)	(0.009)	(0.005)	(0.049)
GDP per capita	0.716***	-3.657***	-3.852***	1.149***	1.025***
	(0.025)	(1.369)	(0.318)	(0.038)	(0.111)
GDP per capita_sq	-0.061***	0.159**	0.166***	-0.092***	-0.084***
	(0.002)	(0.066)	(0.015)	(0.003)	(0.008)
GDP per capita_partner	-0.030	9.660***	0.006	-0.017	3.994***
	(0.025)	(3.189)	(0.056)	(0.032)	(0.932)
GDP per capita sq_partner	-0.000	-0.468***	-0.002	0.000	-0.197***
	(0.002)	(0.150)	(0.004)	(0.002)	(0.044)
Resource Rents	-0.049***	-0.267	-0.475***	0.059***	0.074*
	(0.015)	(0.304)	(0.066)	(0.013)	(0.039)
Resource Rents_partner	0.034**	0.453**	0.004	-0.005	0.296***
	(0.014)	(0.195)	(0.019)	(0.014)	(0.076)
Human Capital Index	0.021**	0.168**	0.301***	-0.056***	0.005
	(0.010)	(0.069)	(0.014)	(0.012)	(0.048)
Human Capital Index_partner	-0.010	0.041	-0.012	-0.008	0.015
	(0.011)	(0.037)	(0.031)	(0.015)	(0.020)
Broad Money	0.096***	0.148***	0.124***	0.067***	0.080***
	(0.007)	(0.046)	(0.009)	(0.008)	(0.024)
Broad Money_partner	-0.011*	-0.124**	-0.029**	-0.015*	-0.049***
	(0.006)	(0.053)	(0.013)	(0.008)	(0.016)
FTA_WTO	-0.003	-0.028	0.011	-0.011*	0.033*
	(0.005)	(0.026)	(0.008)	(0.006)	(0.017)
GATT	-0.025***	-0.064	-0.118***	-0.015***	-0.020
	(0.004)	(0.040)	(0.007)	(0.004)	(0.012)
GATT_partner	0.012***	-0.100**	0.021***	0.011***	-0.034**
	(0.003)	(0.039)	(0.008)	(0.004)	(0.016)
Constant	-1.103***	-29.062	21.659***	-2.675***	-22.702***
	(0.143)	(19.803)	(1.693)	(0.192)	(4.921)
# of Obs.	570,816	12,439	74,686	410,349	73,342
R-squared	0.851	0.509	0.622	0.885	0.809

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A4. Greenhouse Gas Emission Intensity Embedded in GVC by Country Groupings, Mining

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
Variables	(1)	(2)	(3)	(4)	(5)
Value-added growth	0.008	0.055	0.110**	0.004	-0.022
	(0.016)	(0.121)	(0.044)	(0.015)	(0.075)
Value-added growth_partner	0.273	-19.572***	-0.665	0.317	0.079
	(0.173)	(5.809)	(0.541)	(0.194)	(0.469)
Capital stock intensity	0.036***	0.129***	0.126***	0.023***	0.032***
	(0.003)	(0.013)	(0.005)	(0.004)	(0.010)
Capital stock intensity_partner	-0.001	-0.001	-0.003	-0.002	0.004
	(0.002)	(0.028)	(0.003)	(0.003)	(0.023)
Renewable energy	-0.085***	-0.072***	-0.077***	-0.071***	-0.074***
	(0.003)	(0.015)	(0.004)	(0.004)	(0.011)
Renewable energy_partner	0.004	0.048	0.005	0.002	-0.012
	(0.006)	(0.074)	(0.009)	(0.007)	(0.067)
GDP per capita	0.596***	-2.115*	-1.905***	0.875***	0.822***
	(0.028)	(1.248)	(0.370)	(0.044)	(0.129)
GDP per capita_sq	-0.048***	0.084	0.073***	-0.068***	-0.063***
	(0.002)	(0.058)	(0.017)	(0.003)	(0.009)
GDP per capita_partner	-0.014	1.761	-0.017	-0.010	0.864
	(0.033)	(1.336)	(0.054)	(0.044)	(1.075)
GDP per capita sq_partner	0.001	-0.089	0.001	0.001	-0.042
	(0.002)	(0.063)	(0.004)	(0.003)	(0.051)
Resource Rents	0.222***	0.277**	0.137***	0.306***	0.332***
	(0.014)	(0.108)	(0.039)	(0.016)	(0.041)
Resource Rents_partner	0.005	0.114	0.005	0.001	0.023
	(0.018)	(0.114)	(0.023)	(0.021)	(0.088)
Human Capital Index	0.059***	0.390***	0.290***	-0.029**	-0.040
	(0.014)	(0.110)	(0.039)	(0.014)	(0.038)
Human Capital Index_partner	0.000	0.040	-0.011	0.003	0.002
	(0.014)	(0.029)	(0.024)	(0.019)	(0.029)
Broad Money	0.021***	0.095***	0.110***	-0.046***	-0.064**
	(0.007)	(0.021)	(0.008)	(0.011)	(0.029)
Broad Money_partner	-0.007	-0.015	-0.013	-0.007	-0.020
	(0.008)	(0.024)	(0.012)	(0.010)	(0.019)
FTA_WTO	-0.009*	-0.075**	0.003	-0.007	-0.000
	(0.005)	(0.037)	(0.007)	(0.007)	(0.014)
GATT	-0.085***	-0.106***	-0.087***	-0.077***	-0.091***
	(0.007)	(0.026)	(0.009)	(0.007)	(0.018)
GATT_partner	0.002	-0.026	0.007	0.001	-0.010
	(0.004)	(0.039)	(0.006)	(0.005)	(0.019)
Constant	-1.333***	3.093	11.259***	-2.207***	-6.532
	(0.180)	(8.988)	(1.959)	(0.250)	(5.618)
# of Obs.	284,755	6,105	36,690	205,277	36,683
R-squared	0.908	0.606	0.674	0.926	0.884

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A5. Greenhouse Gas Emission Intensity Embedded in GVC by Country Groupings, Construction

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
Variables	(1)	(2)	(3)	(4)	(5)
Value-added growth	0.001	0.074	0.069	0.000	-0.054
	(0.009)	(0.168)	(0.067)	(0.009)	(0.107)
Value-added growth_partner	-0.007***	-	-0.002**	0.006	0.728*
	(0.002)		(0.001)	(0.011)	(0.407)
Capital stock intensity	0.028***	0.224***	0.213***	0.018***	0.019**
	(0.003)	(0.018)	(0.007)	(0.003)	(0.008)
Capital stock intensity_partner	-0.000	0.017	-0.002	0.001	0.015
	(0.002)	(0.029)	(0.003)	(0.002)	(0.018)
Renewable energy	-0.070***	0.134***	0.146***	-0.068***	-0.079***
	(0.003)	(0.043)	(0.014)	(0.004)	(0.010)
Renewable energy_partner	-0.005	0.119	-0.005	-0.006	0.082
	(0.006)	(0.084)	(0.011)	(0.007)	(0.062)
GDP per capita	0.691***	-6.443***	-5.262***	1.082***	1.135***
	(0.030)	(0.855)	(0.292)	(0.048)	(0.126)
GDP per capita_sq	-0.059***	0.288***	0.232***	-0.088***	-0.093***
	(0.002)	(0.040)	(0.014)	(0.004)	(0.009)
GDP per capita_partner	-0.011	-0.885	-0.011	-0.027	-1.540*
	(0.030)	(1.127)	(0.045)	(0.040)	(0.864)
GDP per capita sq_partner	0.001	0.042	0.000	0.001	0.076*
	(0.002)	(0.053)	(0.003)	(0.003)	(0.041)
Resource Rents	0.011	-0.374***	-0.383***	0.153***	0.144**
	(0.023)	(0.139)	(0.046)	(0.024)	(0.059)
Resource Rents_partner	-0.040**	0.026	-0.024	-0.022	-0.088
	(0.018)	(0.144)	(0.028)	(0.019)	(0.097)
Human Capital Index	-0.042***	0.359***	0.370***	-0.169***	-0.178***
	(0.012)	(0.039)	(0.013)	(0.014)	(0.039)
Human Capital Index_partner	-0.004	-0.012	-0.018	-0.010	-0.012
	(0.013)	(0.029)	(0.021)	(0.018)	(0.026)
Broad Money	0.056***	0.083***	0.054***	0.036***	0.058**
	(0.007)	(0.026)	(0.008)	(0.010)	(0.027)
Broad Money_partner	0.018***	0.029	0.014	0.018*	0.034**
	(0.007)	(0.023)	(0.013)	(0.009)	(0.015)
FTA_WTO	-0.007	0.001	0.013*	-0.010	0.017
	(0.006)	(0.021)	(0.007)	(0.008)	(0.016)
GATT	-0.010**	-0.030	-0.042***	-0.002	0.000
	(0.004)	(0.023)	(0.007)	(0.004)	(0.011)
GATT_partner	-0.002	0.043	-0.004	-0.002	0.045**
	(0.004)	(0.039)	(0.006)	(0.005)	(0.018)
Constant	-1.071***	39.593***	28.841***	-2.171***	5.307
	(0.171)	(7.721)	(1.587)	(0.237)	(4.597)
# of Obs.	283,728	6,219	37,343	203,756	36,410
R-squared	0.904	0.737	0.790	0.917	0.898

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A6. Greenhouse Gas Emission Intensity Embedded in GVC by Country Groupings, Electricity, Gas and Water

	Total	**Developed-Developed**	**Developed-Developing**	**Developing-Developing**	**Developing-Developed**
Variables	(1)	(2)	(3)	(4)	(5)
Value-added growth	0.001	0.011	0.056	-0.002	0.508
	(0.010)	(0.106)	(0.082)	(0.007)	(0.546)
Value-added growth_partner	0.275	0.019	-0.052	0.325	-0.245
	(0.425)	(0.084)	(0.173)	(0.507)	(0.798)
Capital stock intensity	0.868***	0.295***	0.273***	0.894***	0.898***
	(0.010)	(0.050)	(0.014)	(0.011)	(0.032)
Capital stock intensity_partner	-0.004	-0.000	-0.000	0.004	-0.062
	(0.005)	(0.050)	(0.003)	(0.005)	(0.057)
Renewable energy	-0.042**	-0.241***	-0.309***	-0.059***	-0.015
	(0.020)	(0.087)	(0.025)	(0.021)	(0.064)
Renewable energy_partner	-0.073***	0.045	-0.008	-0.040**	-0.245*
	(0.017)	(0.100)	(0.015)	(0.020)	(0.126)
GDP per capita	-0.052	-5.511***	-3.135***	-0.299**	-0.925***
	(0.089)	(1.238)	(0.340)	(0.118)	(0.328)
GDP per capita_sq	-0.005	0.267***	0.148***	0.010	0.055***
	(0.005)	(0.061)	(0.016)	(0.007)	(0.020)
GDP per capita_partner	0.028	-5.259**	-0.001	0.074	-22.030***
	(0.070)	(2.460)	(0.066)	(0.094)	(2.661)
GDP per capita sq_partner	0.008*	0.263**	0.001	-0.000	1.107***
	(0.005)	(0.117)	(0.005)	(0.006)	(0.126)
Resource Rents	-0.096*	-0.461***	-0.342***	-0.077	-0.126
	(0.055)	(0.169)	(0.066)	(0.062)	(0.191)
Resource Rents_partner	-0.251***	-0.394**	-0.026	-0.076*	-2.058***
	(0.043)	(0.192)	(0.028)	(0.044)	(0.215)
Human Capital Index	0.041	0.330***	0.362***	-0.218***	-0.169
	(0.034)	(0.041)	(0.012)	(0.044)	(0.127)
Human Capital Index_partner	0.036	-0.041	-0.010	0.016	-0.153**
	(0.032)	(0.034)	(0.036)	(0.048)	(0.061)
Broad Money	0.231***	0.084***	0.064***	0.318***	0.340***
	(0.015)	(0.024)	(0.008)	(0.025)	(0.074)
Broad Money_partner	0.048***	0.061	0.033**	0.146***	0.199***
	(0.017)	(0.042)	(0.017)	(0.022)	(0.047)
FTA_WTO	0.007	0.013	0.000	-0.019	0.138***
	(0.012)	(0.029)	(0.010)	(0.015)	(0.032)
GATT	-0.002	0.021	-0.047**	-0.022*	-0.027
	(0.011)	(0.094)	(0.020)	(0.012)	(0.032)
GATT_partner	-0.076***	0.095**	-0.021**	-0.094***	0.234***
	(0.010)	(0.048)	(0.008)	(0.012)	(0.060)
Constant	0.539	53.858***	15.926***	2.386***	114.411***
	(0.463)	(16.496)	(1.804)	(0.618)	(14.195)
# of Obs.	280,994	5,993	36,035	202,744	36,222
R-squared	0.909	0.928	0.955	0.899	0.866

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A7. Greenhouse Gas Emission Intensity Embedded in GVC by Sectors

Variables	**Total** (1)	**Manufacturing** (2)	**Service** (3)	**Agriculture & Fishing** (4)	**Mining** (5)	**Construction** (6)	**EGW** (7)
Value-added growth	-0.000	0.003	0.008***	-0.004	0.008	0.001	0.001
	(0.011)	(0.006)	(0.003)	(0.011)	(0.016)	(0.009)	(0.010)
Value-added growth_partner	-0.007	-0.000	-0.004	-0.081	0.273	-0.007***	0.275
	(0.006)	(0.011)	(0.072)	(0.109)	(0.173)	(0.002)	(0.425)
Capital stock intensity	0.060***	0.036***	0.056***	0.001	0.036***	0.028***	0.868***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.010)
Capital stock intensity_partner	-0.001*	-0.001	-0.000	-0.001	-0.001	-0.000	-0.004
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.005)
Renewable energy	-0.043***	-0.053***	-0.026***	-0.060***	-0.085***	-0.070***	-0.042**
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.020)
Renewable energy_partner	0.011***	0.020***	0.012***	0.017***	0.004	-0.005	-0.073***
	(0.002)	(0.003)	(0.002)	(0.005)	(0.006)	(0.006)	(0.017)
GDP per capita	0.687***	0.904***	0.613***	0.716***	0.596***	0.691***	-0.052
	(0.009)	(0.017)	(0.012)	(0.025)	(0.028)	(0.030)	(0.089)
GDP per capita_sq	-0.058***	-0.072***	-0.052***	-0.061***	-0.048***	-0.059***	-0.005
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.005)
GDP per capita_partner	-0.011	-0.020	-0.003	-0.030	-0.014	-0.011	0.028
	(0.009)	(0.015)	(0.011)	(0.025)	(0.033)	(0.030)	(0.070)
GDP per capita sq_partner	-0.000	-0.001	-0.001	-0.000	0.001	0.001	0.008*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.005)
Resource Rents	-0.022***	-0.050***	-0.018**	-0.049***	0.222***	0.011	-0.096*
	(0.006)	(0.012)	(0.007)	(0.015)	(0.014)	(0.023)	(0.055)
Resource Rents_partner	0.018***	0.054***	0.015**	0.034**	0.005	-0.040**	-0.251***
	(0.006)	(0.010)	(0.008)	(0.014)	(0.018)	(0.018)	(0.043)
Human Capital Index	0.003	-0.005	0.010**	0.021**	0.059***	-0.042***	0.041
	(0.004)	(0.007)	(0.004)	(0.010)	(0.014)	(0.012)	(0.034)
Human Capital Index_partner	-0.007*	-0.012	-0.007	-0.010	0.000	-0.004	0.036
	(0.004)	(0.007)	(0.005)	(0.011)	(0.014)	(0.013)	(0.032)
Broad Money	0.058***	0.051***	0.042***	0.096***	0.021***	0.056***	0.231***
	(0.002)	(0.003)	(0.003)	(0.007)	(0.007)	(0.007)	(0.015)
Broad Money_partner	-0.005**	-0.015***	-0.003	-0.011*	-0.007	0.018***	0.048***
	(0.002)	(0.004)	(0.003)	(0.006)	(0.008)	(0.007)	(0.017)
FTA_WTO	-0.009***	-0.012***	-0.012***	-0.003	-0.009*	-0.007	0.007
	(0.002)	(0.003)	(0.003)	(0.005)	(0.005)	(0.006)	(0.012)
GATT	-0.030***	-0.030***	-0.022***	-0.025***	-0.085***	-0.010**	-0.002
	(0.001)	(0.003)	(0.002)	(0.004)	(0.007)	(0.004)	(0.011)
GATT_partner	0.007***	0.015***	0.008***	0.012***	0.002	-0.002	-0.076***
	(0.001)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.010)
Constant	-1.144***	-1.787***	-1.094***	-1.103***	-1.333***	-1.071***	0.539
	(0.052)	(0.091)	(0.067)	(0.143)	(0.180)	(0.171)	(0.463)
# of Obs.	7,115,878	2,549,104	3,146,481	570,816	284,755	283,728	280,994
R-squared	0.880	0.793	0.863	0.851	0.908	0.904	0.909

Notes: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.