INTERNATIONAL MONETARY FUND

Measuring Carbon Emissions of Foreign Direct Investment in Host Economies

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WP/22/86

2022
MAY

WORKING PAPER

 WP/22/86

IMF Working Paper
Statistics Department

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Authorized for distribution by Carlos Sanchez Munoz
May 2022

ABSTRACT: This paper presents estimates of the carbon emissions of FDI from capital formation funded by FDI and the production of foreign-controlled firms. The carbon intensity of capital formation financed by FDI has trended down, driven by reductions in the carbon intensity of electricity generation. Carbon emissions from the operations of foreign-controlled firms are greater than those from their capital formation. High emission intensities were accompanied by high export intensities in mining, transport, and manufacturing. Home country policies to incentivize firms to meet strict emissions standards in both their domestic and foreign operations could be important to reducing emissions globally.

JEL Classification Numbers:	F21 International Investment; F23 Multinational Firms; F64 Economic Impacts of Globalization: Environment
Keywords:	Carbon emissions, foreign direct investment, input-output tables
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WORKING PAPERS

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Prepared by Maria Borga, Achille Pegoue, Gregory Max Henri Legoff, Alberto Sanchez Rodelgo, Dmitrii Entaltsev, and Kenneth Egesa[1]

[1] The authors would like to thank colleagues at the IMF and attendees of the IMF's 9th Statistical Forum "Measuring Climate Change" for constructive comments.

Contents

Glossary

AMNEs	Activity of Multinational Enterprises
DOEs	Domestic Owned Enterprises
FDI	Foreign Direct Investment
GFCF	Gross Fixed Capital Formation
ICIO	Inter-Country Input-Output
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
M&As	Mergers and Acquisitions
MNEs	Multinational Enterprises
OECD	Organization for Economic Cooperation and Development
SPEs	Special Purpose Entities
Rev	Revision
US	United States
WIOD	World Input-Output Database

Executive Summary

This paper presents a statistical framework for estimating the carbon emissions associated with foreign direct investment (FDI) in host economies. There are two sets of estimates. The first measures carbon emissions from capital formation funded by FDI that is associated with, for example, the construction of new plant and equipment. The second set of estimates measures direct and indirect carbon emissions from the production of foreign-owned firms. The empirical evidence on the impact of FDI on carbon emissions in host economies is a first step in untangling the relationship between the offshoring of multinational enterprises (MNEs) and global carbon emissions. The framework is also used to develop comparable estimates of carbon emissions in the host economy from operations of non-FDI, or domestic owned, enterprises (DOEs). The methodology is underpinned by the OECD Inter Country Input Output (ICIO) tables linked to carbon emissions, FDI statistics by industry from the OECD, and the OECD Analytical Activity of Multinational Enterprises (AMNE) Database.

The empirical evidence shows that the carbon intensity of gross fixed capital formation (GFCF) financed by FDI has fallen over time, driven in most countries by reductions in the carbon intensity of the electricity, gas, and water industry. Carbon emissions from the ongoing operations of foreign-controlled firms (henceforth MNEs) are larger than those associated with their capital formation. At industry-level, manufacturing; transport and storage; and electricity, gas, and water had the highest overall emissions and emission intensities among MNEs. A comparison between MNEs and DOEs showed that DOEs accounted for the largest share in total emissions and generally had higher carbon intensities, but there were cases in low carbon intensive countries where MNEs had higher carbon intensities. For MNEs, high emissions intensities were accompanied by high export intensities in mining; transport and storage; and manufacturing industries.

Given the high carbon emission intensities of MNEs in high export intensity industries, home country policies that incentivize their domestic direct investors to meet high emissions standards in host economies could be an important tool in reducing global emissions. Addressing data limitations would improve the quality of the estimates, including by developing statistics that identify the FDI flows that are used to expand capacity in the host economy and that identify carbon emissions by MNEs. Finally, expanding country coverage would enable a more comprehensive analysis of the impact of offshoring of MNEs on global carbon emissions.

Introduction

The effects of foreign direct investment[1] (FDI) on host economies are complex as has been recognized by many authors. For instance, FDI has been associated in host economies with rising wages (Rippy, 1976; Harrison, 1995; Lipsey, 2004; and Hill, 1990); higher productivity (Okamoto and Sjholm, 2000; Kokko, Zejan, and Tansini, 2001; and Kathuria, 2000), productivity and knowledge spillovers to domestic firms (Smarzynska, 2004; and Aitken and Harrison, 1991); exports diversification and introduction of new industries (Lipsey, 2000; and Wendy and Chia, 2004) and increasing growth (Romer, 1993; Blomstrom, Lipsey, and Zejan, 1994; Lipsey, 2000; and De Mello, 1999). In relation to environment and sustainability, the effects of FDI are unclear as FDI can affect carbon emissions through multiple channels, including by increasing the scale of economic activity, by contributing to demand for addressing climate change, and by diffusing low-carbon knowledge and technology across borders.

One view is that if demand for environmental quality increases as incomes rise, then eventually environmental damage will begin to fall (the environmental Kuznets curve argument); thus, as FDI increases incomes, it will contribute to this increased environmental demand in host economies. Another view is that FDI is usually associated with higher carbon emissions especially in low-income countries (Zhu, Duan, Guo, and Yu, 2016; Lee, 2013; Shahbaz, Balsalobre-Lorente, and Sinha, 2019; Mabey and McNally, 1999; Seker, Ertugrul, and Cetin, 2015; and Shao, 2018). The main argument is that countries with low incomes tend to set low pollution standards to be able to attract resource seeking as well as pollution intensive FDI (also referred to as the "pollution havens" hypothesis). Proponents of this view recommend, in addition to consumer or financial sector-driven initiatives to improve companies' behavior, the use of mandatory environmental conduct requirements to prevent the best firms being undermined by unscrupulous competitors. A third view is that FDI is cleaner than domestic investment because it deploys new technologies that are cleaner than domestic producers, thus supporting improvements in the environment of the host country (Blackman and Wu, 1999; and Zarsky, 1999). This view, also referred to as the "pollution halos" argument, focuses environmental related outcomes of FDI on the associated positive effects of better management, adherence to higher standards, and use of better technology. Those higher standards could include both those set in the home country of the MNE or other host economies, which could result in positive spillovers to the home and host countries. Thus, FDI could be an important channel for the transfer of low-carbon technology across borders (Pigato et al, 2020).

In this paper, we do not take or attempt to test any particular view, but rather focus on contributing to the ongoing debate on the effect of FDI on the environment by developing a framework for estimating its contributions to carbon emissions. The framework relies on industry level information on production, trade, investment, carbon emissions, and distinction between MNEs and DOEs to produce estimates of the carbon emissions from FDI and the operations of foreign-owned firms. The data used for the analysis makes it possible to derive estimates of carbon emissions directly from the investment and production activities of MNEs as well as the indirect emissions from, for example, their use of electricity generated within the host economy. While the framework can produce such estimates, limitations in the data currently available require that some strong

[1] FDI is a form of cross-border investment in which an investor resident in one economy establishes a lasting interest in and a significant degree of influence over an enterprise resident in another economy. Ownership of 10 percent or more of the voting power is evidence of an FDI relationship.

assumptions be made. Work underway to address some of these limitations will greatly enhance the analytical usefulness of the framework and resulting estimates.

These estimates are an attempt to quantify the outcomes of the three main potential effects cited in the literature as discussed above. Thus, this paper aims at providing a simple and replicable framework that can be useful for answering the following three key questions about FDI and emissions for a given country:

i. What is the effect on carbon emissions of direct investment that finances investments in new productive capacity, such as new plant and equipment?

ii. What is the contribution to emissions from the operations (i.e., economic activity) of foreign owned enterprises in host economies?

iii. Does the production of foreign-owned firms, as well as the emissions embodied in that production, meet domestic demand or is it exported to meet foreign demand?

The first set of indicators that are developed focuses on addressing the first question by examining the financing role of FDI. FDI flows are often used for new investments (greenfield investments) and/or for extensions of capacity of existing enterprises. Each of these investment activities results in gross fixed capital formation[2] (GFCF) in the host economy, which is associated with carbon emissions in the industries that supply the respective products that go into GFCF. The second set of indicators aims to address the second question by providing estimates of emissions from the ongoing operations of MNEs in the host economy. In addressing the second question, we also develop comparable estimates of carbon emissions in the host economy from operations of DOEs.[3] The third set of indicators aims to assess the effect of MNEs on emissions in the host economies by offshoring production of goods that ultimately end up being sold to third countries through their international trade activities (i.e., exports). As already highlighted, FDI may serve as a channel for some countries to offshore production of emissions intensive products that have high demand in home economies of the FDI that have more strict environmental regulations. In such cases, FDI may increase emissions in the host economy from the actual production as well as emissions associated with domestic and international transportation associated with imported inputs and exports of final goods.

The rest of the paper is organized as follows: Section 2 presents the methodology and data used for developing the estimates and also discusses some of the methodological and data limitations. In Section 3, we present and discuss some key results; and Section 4 concludes by discussing some policy implications and highlighting potential areas of further research.

[2] GFCF is the acquisition of assets that are intended to be used in the production of goods and services for a period of more than one year less the disposal of such assets. GFCF is limited to produced assets (i.e., assets that result from a production process) and, thus, exclude non-produced assets, such as land and natural resources. It includes purchases of second-hand assets as well as production of such assets by producers Donefor their own use.

[3] DOEs include both the parent companies of domestic-owned MNEs (i.e., MNEs headquartered in the economy with affiliates in other economies) as well as enterprises that only operate domestically. It would be preferable to distinguish between these two, but the data do not support this.

Methodology and Data Used

A. Estimating the Investment Effect of FDI on Carbon Emissions

One of the benefits of FDI to host economies is expanded production capacity through greenfield investments as well as new investments in existing operations, such as new buildings, infrastructure, machinery, and equipment. When FDI resources are received, they can be used for GFCF which is measured as the total value of a producer's acquisitions less disposals of fixed assets during the accounting period, plus certain specified expenditures on services that add to the value of non-produced assets. However, the process of creating fixed and non-produced assets that are part of GFCF generates carbon emissions by the production units involved in their creation. The main objective of these indicators is to estimate the total amount of carbon emissions that result from the creation of the fixed and non-produced assets by the respective production units that are located in the host economy. We refer to this set of indicators as carbon emissions in supply to GFCF of FDI.

The methodology that was used for estimating the carbon emissions arising from the supply to GFCF funded by FDI involved, first, determining the carbon emissions in supply to GFCF, using the central equation system of input-output analysis and then apportioning the emissions between those funded by FDI and those funded from other sources. To determine the carbon emissions embodied in supplies to gross fixed capital formation, we multiplied estimates of total carbon emissions that include both direct and indirect carbon emissions per unit of output of each supplying industry by its respective output used for GFCF. Direct emissions were based on International Energy Agency (IEA) estimates of carbon emissions from fuel combustion during production based on calculations using the IEA energy data and the default methods and emission factors from the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories[4] (IEA, 2020). The direct emissions relate to Tier 1 carbon emissions from fuel combustion during the production process while indirect emissions relate to carbon emissions embodied in inputs, for example emissions generated to produce cement used as an input for the construction of buildings. These estimates were then multiplied by the estimated amount of GFCF financed by FDI to derive the carbon emissions of capital formation of FDI. The steps followed and source data used were as follows:

Step 1:

Obtaining information on the total emissions emitted during production for each industry for each country.

Step 2:

Estimating the coefficient for the direct emissions (C^{direct}) during production for each industry. This was estimated by dividing total emissions for each industry by its output.

Step 3:

[4] The IEA uses the simplest (Tier 1) methodology to estimate carbon dioxide (CO_2) emissions from fuel combustion based on the 2006 guidelines (https://www.ipcc.ch/site/assets/uploads/2019/05/01_2019rf_OverviewChapter.pdf). The computation follows the concept of conservation of carbon from the fuel combusted into CO_2. Generally, the Tier 1 estimation of CO_2 emissions from fuel combustion for a given fuel can be summarized as the product of fuel consumed and an emission factor. Emissions are then summed across all fuels consumed for each industry.

Estimating the total carbon emission coefficients for the direct and indirect emissions from various industries using estimates of direct carbon emission coefficients and respective domestic input coefficients obtained from input–output tables. The following formula was used:

$$C^{total} = (I - A)^{-1} \cdot C^{direct} \qquad \textbf{(1)}$$

where C^{total} denotes an (n×1) vector of total emission coefficients of direct and indirect emissions, C^{direct} is an (n×1) vector of direct emission coefficients, A is the input coefficient matrix of the input–output table, I is the (n×n) identity matrix, and n is the number of industries. Thus, $(I-A)^{-1}$ is the Leontief inverse matrix.

Step 4:

Estimating total carbon emissions associated with GFCF by adapting the central equation system of input-output analysis through multiplying total carbon emission coefficients derived for each industry by its respective supply for final use in GFCF.

$$Carbon\ emissions\ of\ GFCF = C^{total} \times final\ use\ in\ \ GFCF \qquad \textbf{(2)}$$

Step 5:

Apportioning the total emissions associated with GFCF to FDI by multiplying the share of FDI in GFCF by the total emissions derived in 2.

$$Carbon\ emissions\ of\ GFCF\ of\ FDI = C^{total} \times final\ use\ in\ GFCF\ \times {}^{FDI}\!/_{GFCF} \qquad \textbf{(3)}$$

To enable meaningful comparability between industries and across countries, industry level estimates of carbon emissions in supply to GFCF of FDI were divided by the respective industry level final demand for domestic products, which were derived from the input-output tables.

B. Estimating the Effect of Ongoing Operations of Foreign Owned Enterprises on Carbon Emissions

FDI can increase the scale of economic activity in the host economy, can increase export diversification, and can lead to structural changes in the economy through the introduction of new industries. However, the production activities of the foreign-owned enterprises also generate carbon emissions in the host economy. It is not possible to isolate the operations of all FDI enterprises in the host economy. Nonetheless, data on the activities of MNEs makes it possible to establish operations of a subset of FDI enterprises where direct investors have control.[5] We use the OECD Analytical AMNE Database to track production activity of these foreign-owned firms (henceforth referred to as MNEs) and DOEs over time for individual industries to derive respective estimates of emissions associated with their production activity as follows:

First, we estimated the total carbon emission coefficient of direct and indirect emissions using the Leontief inverse matrix of the ICIO requirement matrix as shown in (4). This Leontief inverse matrix produces direct and indirect output multipliers of countries, MNEs and DOEs by industry, under the assumption that a single matrix merging MNEs and DOEs reflects relationship within MNEs and DOEs and between MNEs and DOEs.

[5] That is, the data on MNEs cover only control relationships while FDI covers both control and influence relationships.

$$C^{total}_{MNEs\,\&\,DOEs} = (I - A_{MNEs\,\&\,DOEs})^{-1} \cdot C^{Direct}_{MNEs\,\&\,DOEs} \quad \textbf{(4)}$$

where $C^{total}_{MNEs\,\&\,DOEs}$ denotes an (n×1) vector of total (direct and indirect) emission coefficients, A is the requirement matrix estimated from the ICIO, I is the (n×n) identity matrix, $(I-A_{MNEs\,\&\,DOEs})^{-1}$ is the Leontief inverse matrix for MNEs and DOEs, and n is the product of the number of countries and the combined number of industries for MNEs and DOEs.

$C^{total}_{MNEs\,\&\,DOEs}$ was further split into C^{total}_{MNEs} and C^{total}_{DOEs} for each country and industry. This breakdown allowed the estimation of carbon emissions in MNEs and DOEs output for final demand (FD) of various countries' industries as follows:

$$Carbon\ emissions\ in\ MNEs\ Output\ for\ FD = C^{total}_{MNEs} \times MNEs\ Output\ for\ FD \quad \textbf{(5)}$$

$$Carbon\ emissions\ in\ DOEs\ Output\ for\ FD = C^{total}_{DOEs} \times DOEs\ Output\ for\ FD \quad \textbf{(6)}$$

C. Estimating the Emissions of MNEs and of Domestic Firms Embodied in Exports

MNEs tend to have higher export intensities than DOEs for a number of reasons, including their role in the creation and management of global value chains and their propensity to be more productive and innovative.[6] The production of exports, like other production, contributes to carbon emissions in the host economy although such emissions are embodied in products that satisfy foreign rather than domestic demand. We estimated the emissions associated with exports of MNEs using reported data on the exports of host countries and industries. We also estimated emissions associated with exports of DOEs for comparison purposes. The estimates are based on the equations shown in (7) and (8).

$$Carbon\ emissions\ of\ Exports\ of\ MNEs = C^{total}_{MNEs} \times Exports\ of\ MNEs \quad \textbf{(7)}$$

$$Carbon\ emissions\ of\ Exports\ of\ DOEs = C^{total}_{DOEs} \times Exports\ of\ DOEs \quad \textbf{(8)}$$

The data that was used in the equations is summarized in the Table 1.

Table 1. Data Sources

Data	Source	Period
Carbon emissions	IEA production-based emissions	2005–15
Output	OECD National Accounts Database	2005–15
Input coefficients	OECD Input Output Database	2005–15
GFCF	OECD National Accounts Database	2005–15
Inward FDI of non-SPEs	OECD FDI financial flows database	2005–15
Final demand	OECD Input Output Database	2005–15
MNEs and DOEs final demand	OECD Analytical AMNE database	2005–15
MNEs and DOEs exports	OECD Analytical AMNE database	2005–15

[6] As mentioned above DOEs also include the parent companies of domestic-owned MNEs. There companies would obviously be more similar to other MNEs than to enterprises that operate only domestically.

MNEs and DOEs input coefficients	OECD Intercountry Input Output Tables from the Analytical AMNE database	2005–15
Source: Authors.		

D. Use of the ICIO of AMNEs

The Analytical AMNE Database tables provide a matrix of the transactions of domestic-owned and foreign-owned firms in 59 countries plus the rest of the world in the host country[7] (Cadestin, et al., 2018). The matrix covers 34 unique industrial sectors over the period 2005–2016. There are four main elements in the Analytical AMNE Database: the intermediate consumption matrix, the final demand matrix, the value-added vector, and the gross output vector. Figure 1 is a compressed extract that shows the intermediate consumption matrix in the shaded parts for illustration purposes. Cells in columns correspond to a country/sector's inputs by ownership; cells in rows correspond to the output of a country/sector by ownership. Gross output of each country is equal to the sum of rows and final demand or the sum of columns and value added. The shaded part shows how each cell of the intermediate consumption matrix for each sector is divided into four cells corresponding to the inputs used by domestic-owned firms from domestic and foreign owned firms and inputs used by foreign-owned firms from domestic and foreign owned firms. The final demand matrix is split across rows to reflect the final demand of products from domestic-owned and foreign-owned firms. The value-added and gross output vectors are split across columns to indicate the value-added and gross output of domestic-owned and foreign-owned firms in each country and sector.

[7] https://www.oecd.org/sti/ind/analytical-AMNE-database.htm#database

Figure 1. Structure of the ICIO Tables for Each Year

			Ctry 1				Ctry 2				Ctry 1	Ctry 2
			Sector 1		Sector 2		Sector 1		Sector 2		Final Demand	Final Demand
			Dom.	For.	Dom.	For.	Dom.	For.	Dom.	For.		
Ctry 1	Sector 1	Dom.										
		For.										
	Sector 2	Dom.										
		For.										
Ctry 2	Sector 1	Dom.										
		For.										
	Sector 2	Dom.										
		For.										
Value added												
Gross output												

E. Data and Methodological Limitations

In the case of carbon emissions from GFCF of FDI, the main data limitation was the absence of FDI data that distinctly finances GFCF. Available estimates for total FDI include funding that could be used for other expenditures besides GFCF. For instance, FDI could be used to finance changes in ownership of existing capital such as with mergers and acquisitions (M&As) or could be used as transit capital through special purpose entities (SPEs). FDI could also be used to acquire financial assets. To address the data limitation related to transit capital, we excluded estimates for countries with large well-known offshore financial centers (Luxemburg, Netherlands, and Ireland). Comparative estimates based on operating entities (excluding SPEs) showed similar trends but are not discussed here due to their unavailability for some of the countries in the sample. Further improvements to the estimates could be made if updates to the international statistical standards, in particular the balance of payments statistical standards, make it possible to obtain a decomposition of FDI by use in the host country.[8]

For estimates associated with the operations of MNEs, the main data limitation was the absence of separate direct carbon emissions data for MNEs and DOEs which meant that the direct emission intensities of MNEs had to be assumed to be the same as DOEs in the same industry. This assumption could be eased with more information on the direct emissions of MNEs; such information would be helpful, for example, in clarifying the

[8] Such a recommendation is under consideration for the update, see guidance note D.1: Direct Investment Task Team (DITT) (imf.org).

impact on emissions of MNEs and DOEs explained fully by differences in their respective production functions and technologies.[9] The overall variation in the total emissions for both MNEs and DOEs that could subsequently be reflected in the estimates we made is mainly due to differences in their industry distribution and sourcing patterns especially between domestic and imported inputs, as reflected by the differences in the respective input coefficients. Better data on the emissions of MNEs, especially by geographic location, and of DOEs would likely result in estimate showing larger differences between the estimates of their carbon intensity. Initiatives to improve corporate reporting of emissions could provide valuable information to help ease this assumption.[10]

Other limitations to the estimates include geographical bias to only OECD countries for the carbon emissions in supply to GFCF of FDI indicator and limitations of the analysis to the period between 2005 and 2015, due to data availability. Further, the central equation system of input-output analysis fails to reflect dynamic interactions between the respective variables. For instance, the timing of the deployment of FDI funds for GFCF could occur with lags, but in the estimation, we assume that there are no lags. Other related caveats of input output analysis pertain to lack of constraints on the factors of production and on the supply side, a fixed input structure and fixed ratios for production for each industry, lack of budget constraints that might prevent households or producers to purchase all additional output, and assumption that households consume goods and services in exact proportion to their initial budget shares. Finally, the direct carbon emissions used in the estimation are based on IEA estimates of carbon emissions from fuel combustion during production derived using the Tier 1 method. We opted to use the IEA estimates because they are available with wider geographic coverage and throughout the period of study. However, some countries may have estimates of carbon emissions based on the more sophisticated Tier 2 or Tier 3 methods that consider detailed available country-specific information (e.g., on different technologies or processes) that we did not use.

Results

A. Carbon Emissions Associated with the Investment Impact of FDI

The results on carbon emissions associated with the investment impact of FDI provide insights into the main sources of emissions in host economies from final use of domestic products for GFCF financed by FDI.[11] They also allow us to undertake a comparison of emissions by industry in a country and between countries. The estimates are in metric tons of emissions and metric tons of emission per 1 million US dollars of output generated to meet final demand. Coverage is for 23 countries[12] during the period 2005 to 2015 and 36

[9] Alternatively, data identifying the home economy of the MNEs would enable the assumption that the MNEs had the same carbon-intensity as DOEs in the same industry in the home economy. This would assume that the foreign operations of MNEs were more similar in carbon intensity to firms in their home economy than to firms in their host economy.

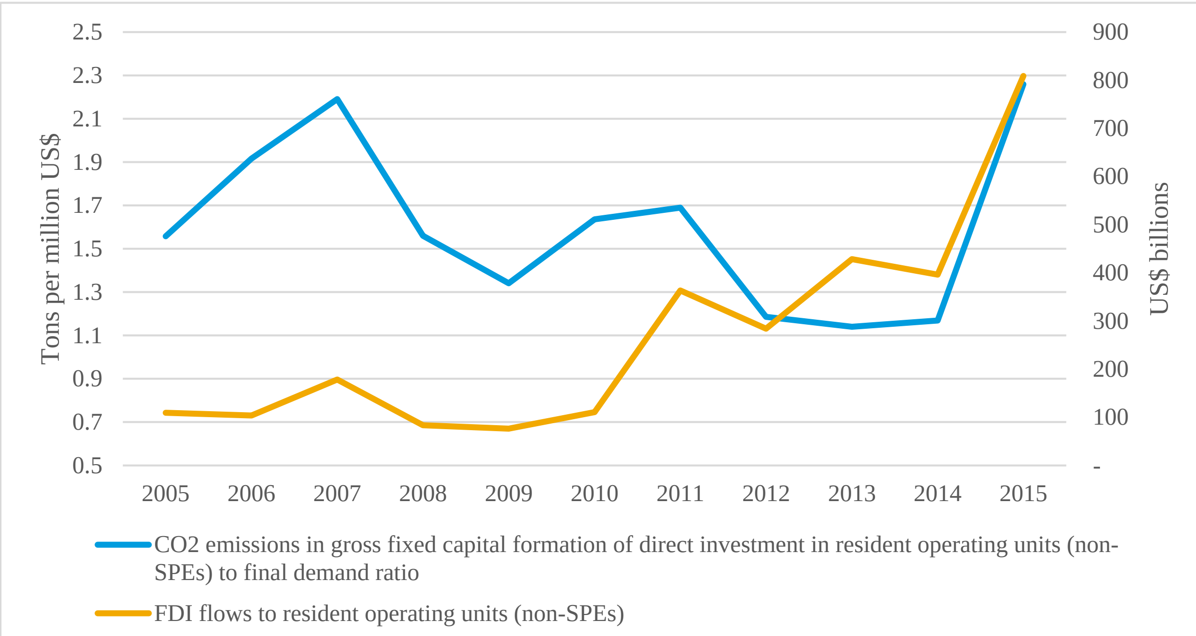
[10] There are several initiatives underway to develop standards for such reporting, including the Financial Stability Board's Task Force on Climate-related Financial Disclosures; the International Financial reporting Standards Foundation's International Sustainability Standards Board; and the work of the Sustainability Accounting Standards Board on environmental, social, and governance metrics.

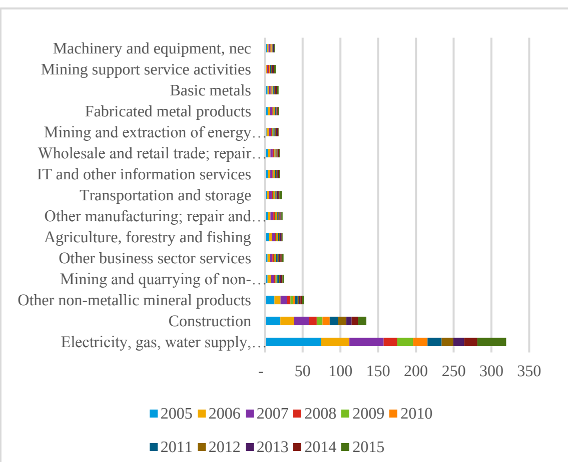
[11] All indicators discussed in this paper are available in the IMF's Climate Change Indicators Dashboard.

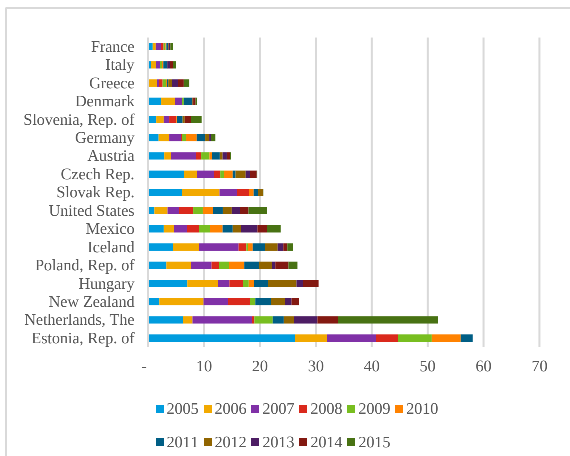
[12] The 23 countries whose estimates are available include Austria, Belgium, Chile, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iceland, Italy, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Slovak, Slovenia, Spain, Sweden, and United States.

industries based on the International Standard Industrial Classification (ISIC) Revision 4 classification. However, for more meaningful comparison between and within countries and industries, we present results for 17 countries that have more complete annual and industry estimates. Figure 2 presents three different charts showing estimates of carbon emissions of GFCF of FDI in metric tons per 1 million US dollars of final demand of domestic output.

Figure 2. Carbon Emissions in GFCF of FDI and FDI flows, 2005–15







Source: Authors' calculations from OECD data.

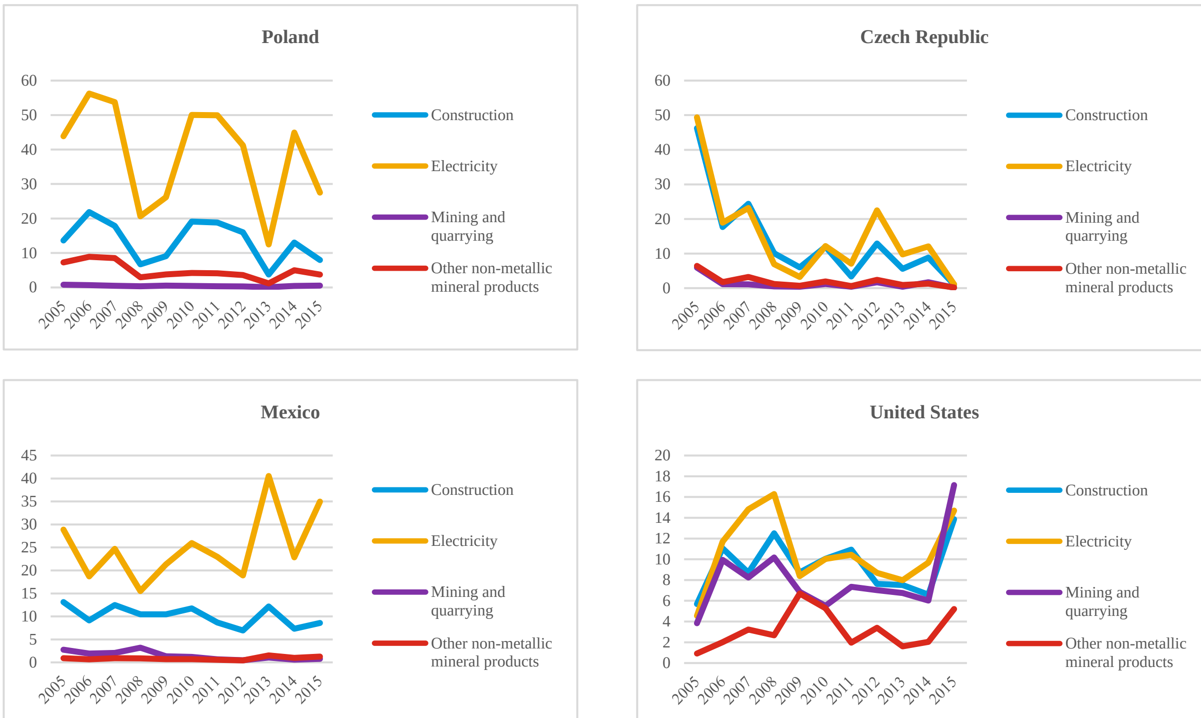
The chart in the top panel shows a comparison of trends in total carbon emissions of GFCF funded by FDI per US$ 1 million of final demand and the total for inward FDI flows for the countries covered. The estimates show a general downward trend in emissions associated with GFCF financed by FDI from 2007 to 2014 despite an increase in FDI flows from 2009. Despite the spike in both emissions and FDI flows in 2015,[13] the trends in emissions and flows suggests that FDI emissions in GFCF funded by FDI has been falling relative to FDI inflows in the later years of the period covered by the analysis.

The bottom left panel of Figure 2 presents the cumulative emissions over the period by industry. The industry with the highest emissions relative to domestic demand was electricity, gas, and water whose emissions were almost three times those of construction, which were the second highest. In terms of shares to total emissions, the electricity, gas, and water industry had an average share of 39 percent of total emissions, followed by construction at 16 percent, manufacturing of other non-metallic mineral products at 6 percent, and mining and quarrying at 3 percent. The contributions of the electricity, gas, and water industry to emissions was highest in countries that relied on fossil fuels for their energy requirements. The estimates also showed that emissions from construction were most significant in countries with large investment projects in the oil and gas industry, while manufacturing industry emissions were more evenly spread across countries. The cumulative emissions by country during the period are shown in the bottom right panel of Figure 2. As shown, the highest emissions during the period were from Estonia, followed by the Netherlands, Hungary, New Zealand, Poland, and Iceland. The lowest emissions were in France, Italy, Greece, and Denmark.

Further disaggregation of the industry composition by country shows varying patterns across countries. Figure 3 shows estimates for the top four industries by size of emissions in Poland, Czech Republic, Mexico, and the US. In Poland, there was a slight decline in emissions in construction and electricity while there have been much more significant downward trends in these industries in the Czech Republic. In contrast, emissions in electricity show an upward trend in Mexico and no trend in the US.

[13] The spike in FDI flows in 2015 was due, in part, to corporate inversions involving US firms. Such transactions involve US firms moving their headquarters overseas and are unlikely to lead to capital formation. This emphasizes again the need for statistics to better link FDI financing to capital formation. For more information on corporate inversions in FDI statistics see: The Effects of Corporate Inversions on the International and National Economic Accounts (bea.gov).

Figure 3. Top 4 Industries by Country of Carbon Emissions Related to GFCF of FDI (Tons per 1 Million US Dollars of Final Demand), 2005–15



Source: Authors' calculations from OECD data.

B. Carbon Emissions of Ongoing Operations of MNEs

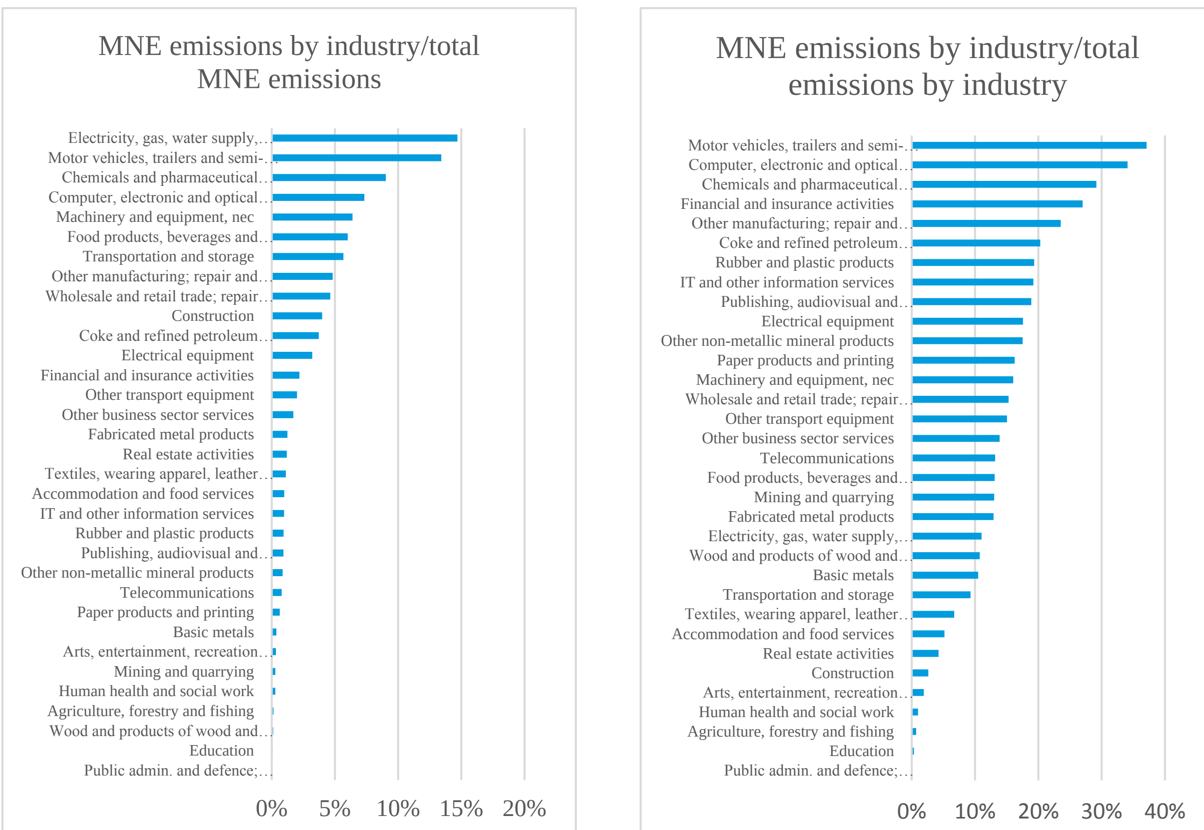
Estimates of carbon emissions from the ongoing operations of MNEs were based on activities of MNEs operating in 59 countries[14] during 2005 to 2015 in 34 industries based on ISIC rev 4. The left panel of Figure 4 shows estimates of total direct and indirect carbon emissions (hereafter referred to as carbon emissions) by industry embodied in the output of MNEs used for final demand. Manufacturing made the largest contribution to emissions of MNEs when all sub-sectors are combined, but when manufacturing is disaggregated, manufacturing of motor vehicles, trailers, and semitrailers and manufacturing of chemicals and pharmaceuticals accounted for 13 percent and 9 percent of total emissions by MNEs, trailing electricity generation with a share of 15 percent. Estimates for the share of carbon emissions of MNEs within each industry are shown in the right panel of Figure 4. According to the estimates, the share of emissions accounted for by MNEs was highest in manufacturing of motor vehicles, trailers, and semitrailers; manufacturing of computer electronics and optical

[14] The countries whose estimates are available are Morocco, Argentina, Australia, Austria, Belgium, Bulgaria, Brazil, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hong Kong SAR, Croatia, Hungary, Indonesia, India, Ireland, Iceland, Israel, Italy, Japan, Korea, Lithuania, Luxembourg, Latvia, Mexico, Malta, Malaysia, Netherlands, Norway, New Zealand, Philippines, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Sweden, Thailand, Turkey, Chinese Taipei, United States, Viet Nam, and South Africa.

products; and manufacturing of chemicals and pharmaceuticals at 37 percent, 34 percent, and 29 percent, respectively. The shares of emissions accounted for by MNEs in construction and agriculture were low despite the two sectors having fairly high carbon intensities, signifying the limited role of MNEs in the two sectors.

Figure 5 shows estimates of the direct and indirect carbon intensity (hereafter referred to as carbon intensity) of final demand for products produced by MNEs compared to DOEs; carbon intensity is measured in metric tons of emissions per 1 million US dollars of output. The left panel presents the industry distribution and shows that electricity, manufacturing of non-metallic mineral products, manufacturing of basic metals, and transportation and storage had the highest carbon intensities. The estimates also show that the carbon intensities of MNEs were lower than that of DOEs in almost all industries with the exceptions of transport and storage; construction; and in some manufacturing subsectors, including wood and wood products; machinery and equipment; motor vehicles; and textiles.

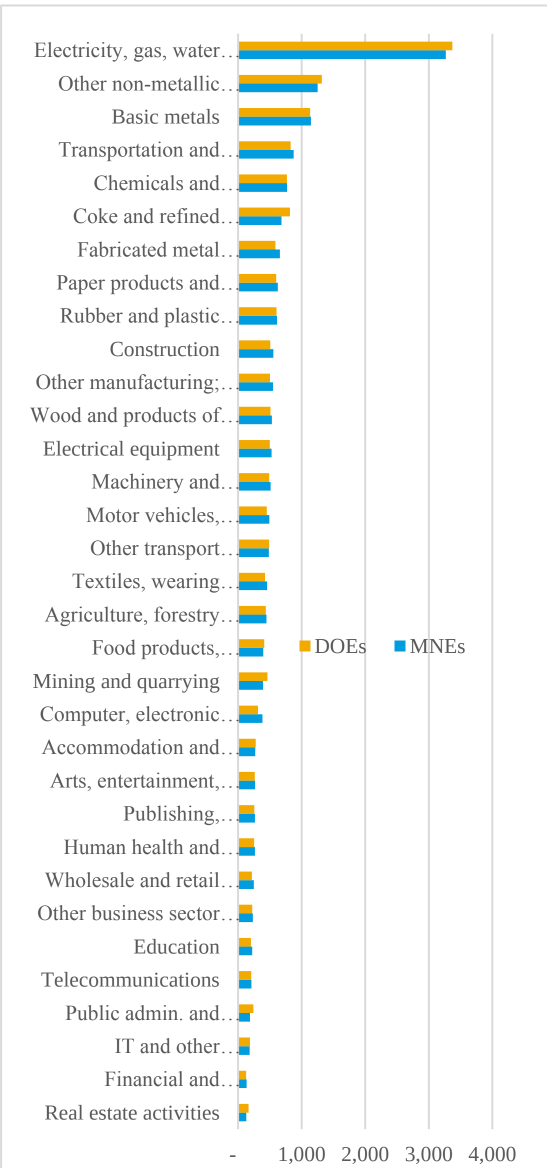
Figure 4. Carbon Emissions in MNEs Output, 2005–15 Average

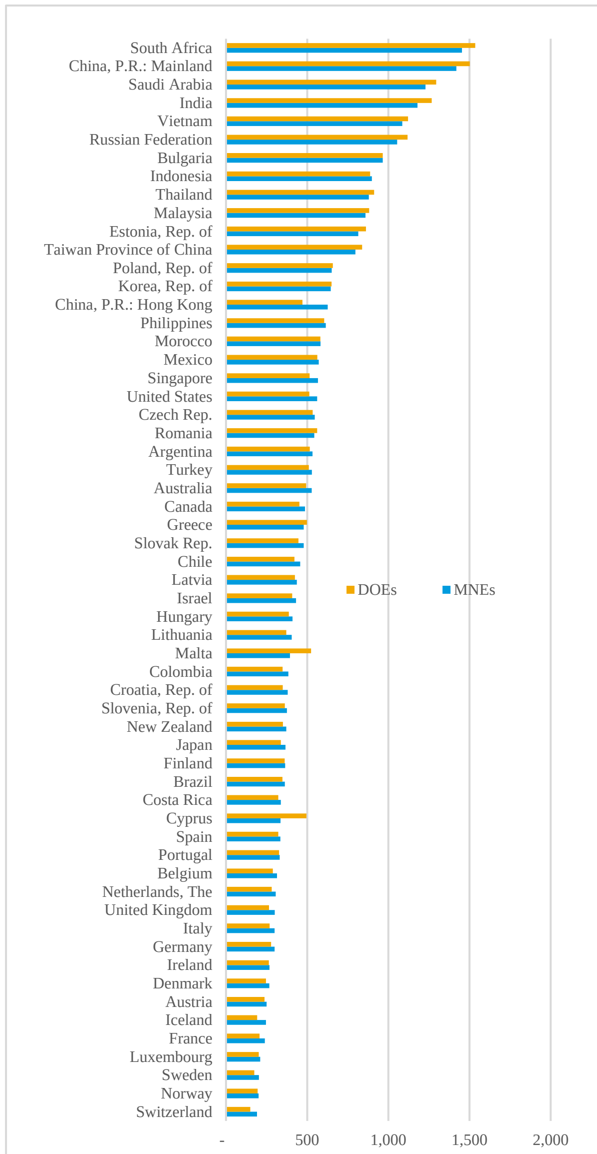


Source: Authors' calculations from OECD data.

The right panel of Figure 5 shows estimates of the carbon intensity of MNEs and DOEs by country. South Africa had MNEs with the highest carbon intensity followed by China, Saudi Arabia, India, and Vietnam. MNEs in Switzerland, Norway, Sweden, Luxemburg, and France had the lowest average intensities. DOEs had higher carbon intensities than MNEs in the dozen countries with the highest carbon intensities with the exception of Indonesia. In contrast, MNEs in low carbon intensity countries had higher carbon intensities than DOEs with the exception of Cyprus. The largest differences between carbon intensities of MNEs and DOEs were in Cyprus and Malta (where DOEs exceeded MNEs) and in Hong Kong SAR, Switzerland, and Iceland (where MNEs exceeded DOEs).

Figure 5. Carbon Intensities of Output (Tons per 1 Million USD), 2005–15 Average

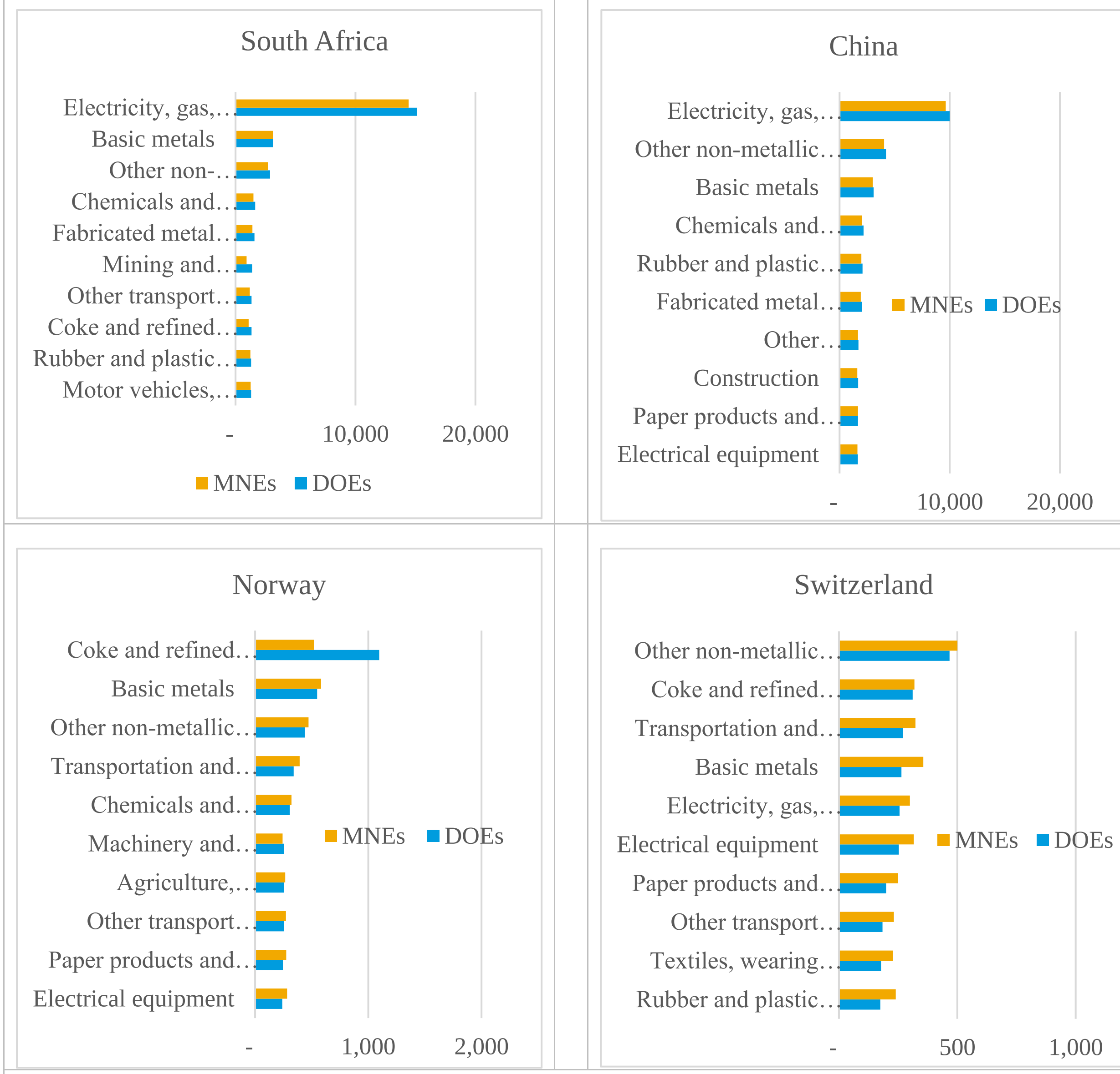




Source: Authors' calculations from OECD data.

Figure 6 compares the industry-level carbon intensities between selected economies with overall high carbon intensities (China and South Africa) and overall low carbon intensities (Norway and Switzerland). In China and South Africa, electricity, gas, and water had the highest intensity; while in Norway and Switzerland, manufacturing industries had the highest intensities. Looking more broadly, the difference between the carbon intensity of MNEs and DOEs in high carbon intensive economies was quite small with the exception of the electricity, gas and water industry. However, for the low carbon intensive economies, differences in the carbon intensity of MNEs compared to DOEs were much larger.

Figure 6. Carbon Intensities of Output (Tons per 1 Million USD), 2005–15 Average



Source: Authors' calculations form OECD data.

Estimates of trends in the carbon intensities of MNEs between 2005 and 2015 for selected industries with large carbon intensities for the five countries with the highest carbon intensities in each industry are shown in

Figure 7. In manufacturing of basic metals, MNEs in South Africa had the highest intensities in 2015 followed by India, Russia, China, and Saudi Arabia; there has been a general downward trend with the exceptions of India and South Africa. In electricity, MNEs in South Africa, Saudi Arabia, India, Estonia, and China has shown a general downward trend in all countries. In the manufacture of other non-metallic mineral products, Vietnam, Thailand, the Philippines, India, and China showed a general downward trend with the exception of Vietnam. In transport and storage, MNEs in Malta, Singapore, Saudi Arabia, China, and Thailand had the highest intensities; the decline noted during the middle of the period had ceased with the latter period showing an uptick.

Figure 7. Trends in Carbon Intensities of MNEs Output (Tons per 1 Million USD), 2005–15 Average

Source: Authors’ calculations from OECD data.

C. Carbon Emissions in Exports of MNEs

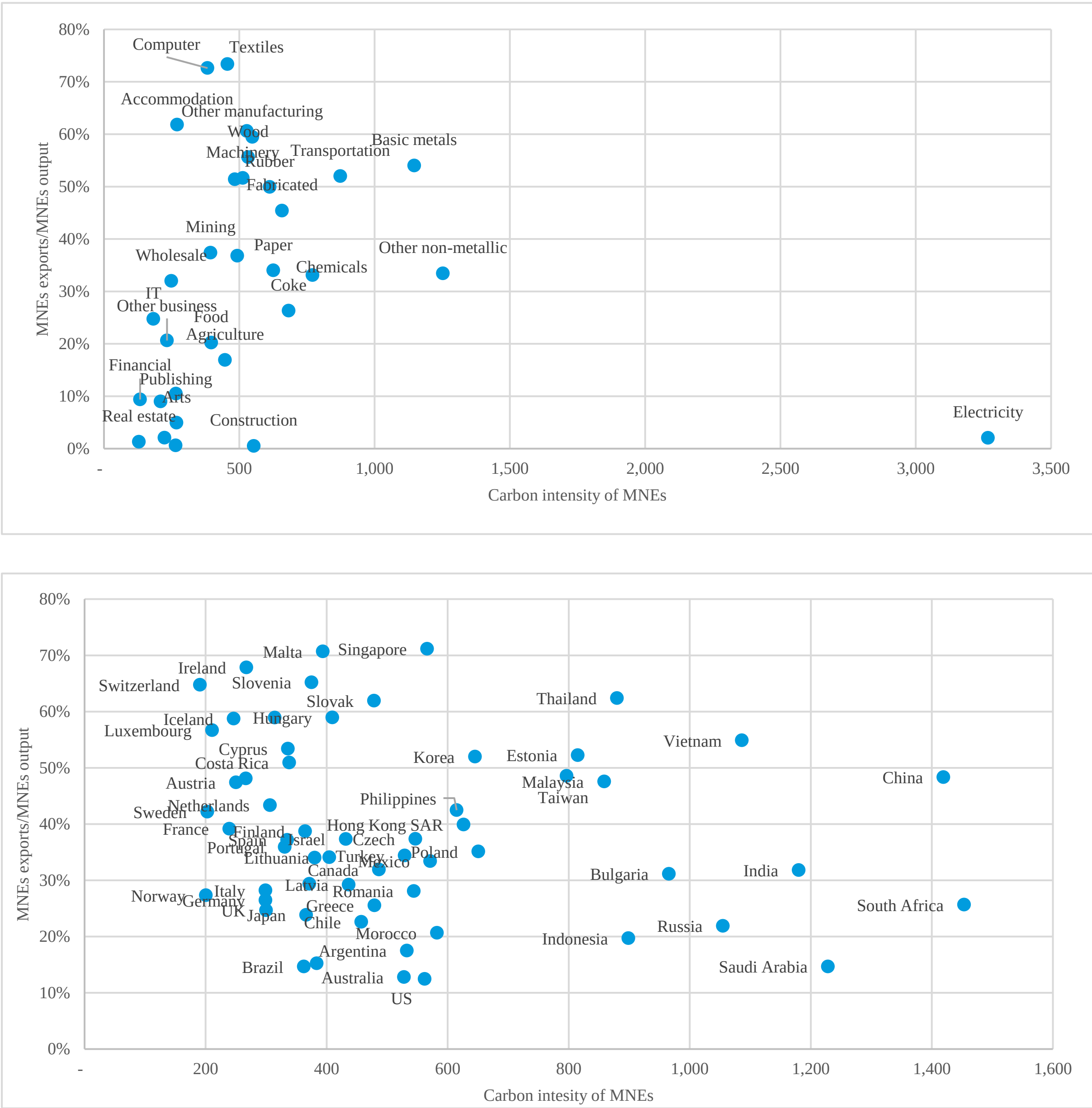
In this subsection, we examine the exporting behavior of MNEs and DOEs to determine the effect of external demand on their emissions. In the top panel of Figure 8, we plot industry carbon intensities of MNEs against the corresponding shares of emissions in exports to total emissions of MNEs. In the lower panel, carbon intensities of MNEs by country are plotted against the corresponding shares of emissions in exports to total emissions of MNEs.[15]

In the top panel, except for electricity, industries with high carbon intensities among MNEs (transport, and manufacture of basic metals, of chemicals and pharmaceutical products, and of non-metallic mineral products) have export intensities between 30 and 60 percent, suggesting that a significant share of the emissions in high carbon intensity industries is driven by foreign demand. In addition, several low carbon intensity industries of MNEs (accommodation and manufacture of textiles, of electrical equipment, of machinery, and of computer and electronic products) also have most of their output exported, which makes their combined effect on domestic emissions by MNEs to meet foreign demand significant.

In the lower panel, a similar observation is made, as countries with fairly low carbon intensities have large shares of their output exported. The implication is that a sizeable share of the emissions in the low carbon intensity countries is driven by foreign demand. For instance, the chart shows that although MNEs in countries like Ireland, Hungary, Iceland, Luxemburg, Cyprus, Slovenia, Switzerland, and Costa Rica have relatively low emission intensities, more than half of their output is exported. Notable exceptions include China, Vietnam, and Thailand that have both high carbon intensity and export shares.

[15] Sectors with export shares less than 30 percent are not shown in the top panel: IT and other information services; Coke and refined petroleum products; Other business sector services; Food products, beverages, and tobacco; Other non-metallic mineral products; Agriculture, forestry, and fishing; Financial and insurance activities; Publishing, audiovisual, and broadcasting activities; Telecommunications; Arts, entertainment, recreation, and other service activities; Education; Electricity, gas, water supply, sewerage, waste, and remediation services; Real estate; Construction; Human health and social work; and Public administration. and defense. Countries with export shares less than 45 percent are not shown in the lower panel: Bulgaria, Poland, Lithuania, Portugal, Norway, Hong Kong SAR, India, France, South Africa, Germany, Colombia, Russian Federation, United Kingdom, Turkey, Latvia, Spain, Australia, Romania, Greece, Croatia, Italy, Argentina, New Zealand, Japan, United States, and Brazil.

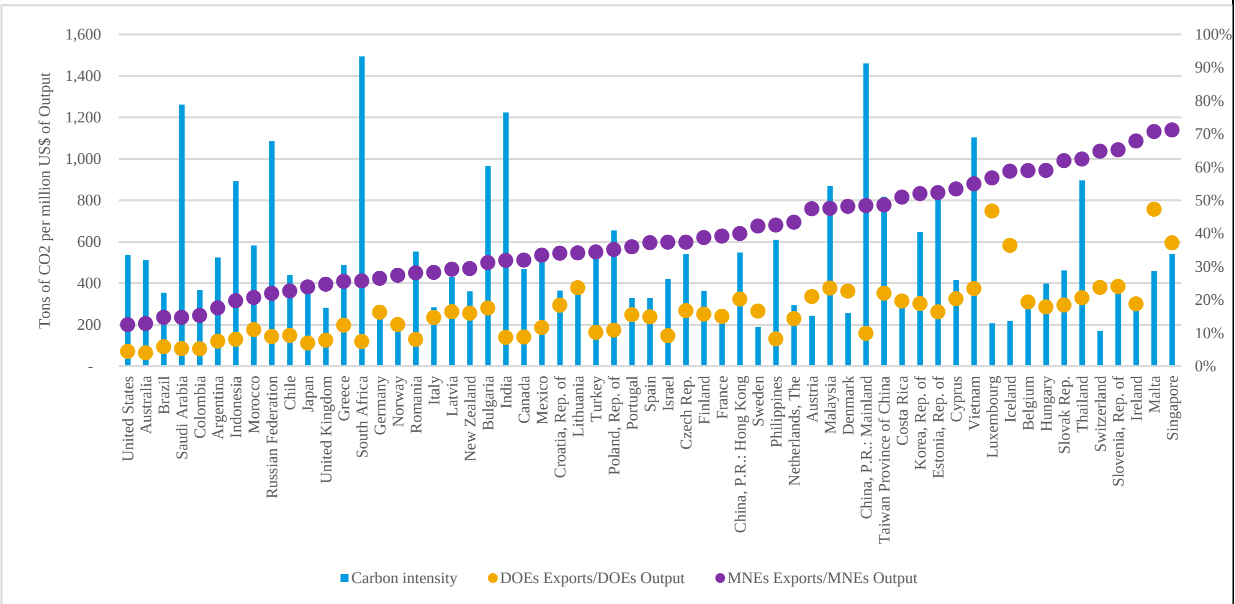
Figure 8. MNE Carbon and Export Intensities, 2005–15 Average



Source: Authors' calculations from OECD data.

In Figure 9, we compare the share of MNEs emissions in exports to respective emissions in their output against corresponding estimates for DOEs by country and superimpose a bar chart for the carbon intensity. Export related emissions shares are higher for MNEs compared to DOEs in all countries. In countries with lower carbon intensities, the gap between the export shares of emissions of MNEs and DOEs tends to be higher with some exceptions, including Luxemburg and Lithuania. The reverse is also true as economies with higher carbon intensities tend to have smaller gaps between the export shares of emissions of MNEs and DOEs; notable exceptions include China, India, South Africa, Vietnam, and Thailand.

Figure 9. Carbon Intensities and Shares of Export Emissions to Output Emissions, 2005–15 Average



Source: Authors' calculations from OECD data.

Conclusions and Policy Implications

This paper presented an experimental approach for estimating the effect of FDI on carbon emissions in host economies through their investment, production, and export related activities. The novel contribution of the approach is two-fold—first it makes use of already available data, and second it is intuitive, and easy to follow and replicate for many countries as data becomes available. The estimates obtained were comparable within and between industries and countries. More importantly, the framework can be used to answer important policy questions on the effect of FDI on emissions. The estimates showed that emissions from the investment activity of FDI have generally fallen between 2005 and 2015. In addition, they are concentrated in electricity, construction, and manufacturing industries. We also found that emissions from operations of FDI companies were greater than emissions from investment activity funded by FDI.

For emissions from the ongoing operations of FDI companies, high carbon emissions for MNEs were mainly in manufacturing; transport; and the electricity, gas, and water industries. The same industries also had the highest carbon intensities. The construction industry, which had a large effect on emissions for FDI-funded GFCF, was not a major contributor to emissions from the ongoing operations of MNEs. Further, MNEs were found to generally have lower contributions to overall emissions and carbon intensities in most sectors compared to DOEs. However, within individual industries in some countries, there were cases were MNEs had higher carbon intensities compared to DOEs, especially in countries with low overall carbon intensities. The results also showed that MNEs in industries with high carbon intensities tended to have high export intensities, suggesting an important role of foreign demand. In addition, we noted that MNEs in countries with the highest export intensities generally had lower carbon intensities with some key exceptions, including China, Vietnam, and Thailand.

The work has shown the important role that firms operating in one economy but owned by investors in another economy have in global carbon emissions. This suggests that policies by home and host economies could play an important role in reducing global carbon emissions. For home countries, policies that incentivize their domestic direct investors to meet high environmental and emissions standards not only in their operations in the home economy but also at their foreign operations could be important to reducing emissions globally and not just domestically. Such policies could not only reduce emissions by inducing these firms to use lower carbon production functions and technology at home and abroad but also by inducing them to demand lower carbon infrastructure and transportation in the host economies. If firms were also encouraged to reduce emissions along their supply chains, it could lead them to demand that their suppliers reduce their carbon emissions. For host economies, it is important to remove barriers to investment in environmental goods and services industries as well as in low carbon technologies to promote positive spillovers and knowledge and technology transfer to the domestic economy. In addition, host economies should include an analysis of the impact on carbon emissions as part of their FDI attraction strategies. Finally, developing a standard for companies to disclose their carbon emissions will provide valuable information that can help us better understand the role of all enterprises, both MNEs and DOEs, in carbon emissions.

There are, however, some methodological and data limitations to the framework. In the future, work could aim to improve the framework by addressing some of these limitations. Possible interesting areas of future work include FDI estimates that distinguish between the use of FDI resources for acquisition of assets versus for greenfield investment and capacity extension; expanded information on the role of MNEs in carbon emissions such as actual estimates of direct carbon emissions of MNEs by activity/sector; and the use of models to capture dynamic interactions. Some sensitivity analysis on the differences in direct emissions between MNEs and DOEs is another important area that could provide additional policy implications on how to structure climate related incentive schemes.

In addition to easing some of the strong assumptions that were made through developing new data, there are several routes for future analysis using the resulting estimates. It would be interesting to explore whether there are spillovers in the form of reduced carbon intensity at DOEs from the operations of MNEs in the host economy. It would also be interesting to better understand the relationship between FDI’s role in production and export diversification and the country’s carbon emissions.

Annex I. Working Example on Computing Emission Estimates

Emissions

Agriculture	Manufacturing	Services	Total
480	440	160	1080

Input-Output tables

To (Columns) / From (Rows)	Agriculture	Manufacturing	Services	Households (HFCE)	Exports	Total Output	Final use
Agriculture	100	500	400	500	100	1600	600
Manufacturing	200	500	500	500	500	2200	1000
Service	400	400	300	400	100	1600	500
Value Added (COE, GOS, GMI)	800	600	300				1700
Imports	100	200	100				1600
Total Inputs	1600	2200	1600	1400	600	5400	
Total Domestic Intermediate	700	1400	1200			5400	

Check	
Supply	Use
1600	1600
2200	2200
1600	1600

Requirements Matrix (A)

To (Columns) / From (Rows)	Agriculture	Manufacturing	Services
Agriculture	0.06	0.23	0.25
Manufacturing	0.13	0.23	0.31
Service	0.25	0.18	0.19

Identity Matrix (I)		
1	0	0
0	1	0
0	0	1

(I-A)			
	0.94	-0.23	-0.25
	-0.13	0.77	-0.31
	-0.25	-0.18	0.81

Check: (I-A)-1xY=X
1600
2200
1600

Leontif Inverse (Multipliers)

	Agriculture	Manufacturing	Services	Total
Agriculture	1.30	0.52	0.60	2.42
Manufacturing	0.41	1.59	0.74	2.73
Service	0.49	0.52	1.58	2.59
Total	2.19	2.63	2.92	

Direct emissions coefficients	0.30	0.2	0.1

Direct and indirect emissions coefficients (emissions multipliers)			
Total	0.519	0.526	0.485
Rearrangement for CO2 content in final use	0.519	0.000	0.000
	0.000	0.526	0.000
	0.000	0.000	0.485

HFCE diagonal				
Agriculture	500	0.00	0	
Manufacturing	0	500.00	0	
Services	0	0.00	400	
Embodied emissions - HFCE	259.7339782	262.8778718	194.050786	716.663

Exports diagonal				
Agriculture	100	0	0	
Manufacturing	0	500	0	
Services	0	0	100	
Embodied emissions - exports	51.94679565	262.8778718	48.51269649	363.337
Total embodied emissions				1080

Output Industry	Contributing Industry	Multiplier	Total direct emissions	Partial direct and indirect emissions	Total direct and indirect emissions
Agriculture	Agriculture	1.30	0.3	0.389	
Agriculture	Manufacturing	0.41	0.2	0.082	
Agriculture	Services	0.49	0.1	0.049	0.519
Manufacturing	Agriculture	0.52	0.3	0.157	
Manufacturing	Manufacturing	1.59	0.2	0.317	
Manufacturing	Services	0.52	0.1	0.052	0.526
Services	Agriculture	0.60	0.3	0.180	
Services	Manufacturing	0.74	0.2	0.147	
Services	Services	1.58	0.1	0.158	0.485

	Households	exports	
Agriculture	259.73	51.95	312
Manufacturing	262.88	262.88	526
Services	194.05	48.51	243
total	716.66	363.34	1080

Annex II. Illustration on the Computation of the Output Multiplier

Suppose $(I-A)=\begin{bmatrix}0 & 2 & 9\\ 1 & 4 & 6\\ 3 & 7 & 8\end{bmatrix}$, then matrix of cofactor is

$$C=\begin{bmatrix}(-1)^{1+1}\begin{vmatrix}4 & 6\\ 7 & 8\end{vmatrix} & (-1)^{1+2}\begin{vmatrix}1 & 6\\ 3 & 8\end{vmatrix} & (-1)^{1+3}\begin{vmatrix}1 & 4\\ 3 & 7\end{vmatrix}\\ (-1)^{2+1}\begin{vmatrix}2 & 9\\ 7 & 8\end{vmatrix} & (-1)^{2+2}\begin{vmatrix}0 & 9\\ 3 & 8\end{vmatrix} & (-1)^{2+3}\begin{vmatrix}0 & 2\\ 3 & 7\end{vmatrix}\\ (-1)^{3+1}\begin{vmatrix}2 & 9\\ 4 & 6\end{vmatrix} & (-1)^{3+2}\begin{vmatrix}0 & 9\\ 1 & 6\end{vmatrix} & (-1)^{3+3}\begin{vmatrix}0 & 2\\ 1 & 4\end{vmatrix}\end{bmatrix}=\begin{bmatrix}-10 & 10 & -5\\ 47 & -27 & 6\\ 24 & 9 & -2\end{bmatrix}.$$

Using the cofactor expression along row i,

determinant of $|I-A|=\sum_{j=1}^{n}(I-A)_{i,j}\,C_{i,j}$, and taking $i=1$, we can compute

$$|I-A|=0\times(-1)^{3+1}\begin{vmatrix}2 & 9\\ 4 & 6\end{vmatrix}+2\times(-1)^{1+2}\begin{vmatrix}1 & 6\\ 3 & 8\end{vmatrix}+9\times(-1)^{1+3}\begin{vmatrix}1 & 4\\ 3 & 7\end{vmatrix}\text{=-25. }(I-A)^{-1}=\frac{1}{-25}=$$
$$\begin{bmatrix}-10 & 47 & 24\\ 10 & -27 & 9\\ -5 & 6 & -2\end{bmatrix}.$$

References

Aitken, B., & Harrison, A., 1991, Are There Spillovers from Foreign Direct Investment? Evidence from Panel Data for Venezuela. World Bank, Washington, DC Mimeo.

Ben-Israel, A., & Greville, T. N., 2003, Generalized Inverses: Theory and Applications. Vol. 15. Springer Science & Business Media.

Blackman, A., & Wu, X., 1999, Foreign Direct Investment in China's Power Sector: Trends, Benefits and Barriers. Energy policy.

Blomstrom, M., Lipsey, R. E., & Zejan, M., 1994, What Explains the Growth of Developing Countries? Convergence of Productivity: Cross-National Studies and Historical Evidence.

Cadestin, C., De Backer, K., Desnoyers-James, I., Miroudot, S., Rigo, D., & Ye, M., 2018, Multinational Enterprises and Global Value Chains: The OECD Analytical AMNE Database.

Climent, J.-J., Thome, N., & Wei, Y., 2001, A Geometrical Approach on Generalized Inverses by Neumann-Type Series. Linear Algebra and Its Applications.

De Mello, L. R., 1999, Foreign Direct Investment-Led Growth: Evidence from Time Series and Panel Data. Oxford Economic Papers.

Harrison, A., 1995, Determinants and Effects of Direct Foreign Investment in Cote d'Ivoire, Morocco, and Venezuela.

Hill, H., 1990, Indonesia's Industrial Transformation Part II. Bulletin of Indonesian Economic Studies.

IEA., 2020, Emissions from Fuel Combustion 2020 Edition.

Kathuria, V., 2000, Productivity Spillovers from Technology Transfer to Indian Manufacturing Firms. Journal of International Development.

Kokko, A., Zejan, M., & Tansini, R., 2001, Trade Regimes and Spillover Effects of FDI: Evidence from Uruguay. Weltwirtschaftliches Archiv.

Lee, J. W., 2013, The Contribution of Foreign Direct Investment to Clean Energy Use, Carbon Emissions and Economic Growth. Energy Policy.

Lipsey, R. E., 2000, Affiliates of US and Japanese Multinationals in Production and Trade. NBER-EASE.

Lipsey, R. E., 2004, Home- and Host-Country Effects of Foreign Direct Investment. In Challenges to Globalization: Analyzing the Economics. University of Chicago Press.

Mabey, N., & McNally, R., 1999, Foreign Direct Investment and the Environment: From Pollution Havens to Sustainable Development. World Wide Fund for Nature United Kingdom, Surrey.

Moulinec, H., Suquet, P., & Milton, G. W., 2018, Convergence of Iterative Methods Based on Neumann Series for Composite Materials: Theory and Practice. International Journal for Numerical Methods in Engineering.

Okamoto, Y., & Sjholm, F., 2000, FDI and the Dynamics of Productivity: Microeconomic Evidence. APEC Study Centre, Graduate School of International Development, Nagoya.

Pigato, Miria A., Simon J. Black, Damien Dussaux, Zhimin Mao, Miles McKenna, Ryan Rafaty, and Simon Touboul., 2020. *Technology Transfer and Innovation for Low-Carbon Development*. International Development in Focus. Washington, DC: World Bank. doi:10.1596/978-1-4648-1500-3.

Romer, P., 1993, Idea Gaps and Object Gaps in Economic Development. Journal of Monetary Economics.

Seker, F., Ertugrul, H. M., & Cetin, M., 2015, The Impact of Foreign Direct Investment on Environmental Quality: A Bounds Testing and Causality Analysis for Turkey. Renewable and Sustainable Energy Reviews.

Shahbaz, M., Balsalobre-Lorente, D., & Sinha, A., 2019, Foreign Direct Investment—CO_2 Emissions Nexus in Middle East and North African Countries: Importance of Biomass Energy Consumption. Journal of Cleaner Production.

Shao, Y., 2018, Does FDI Affect Carbon Intensity? New Evidence from Dynamic Panel Analysis. International Journal of Climate Change Strategies and Management.

Smarzynska, J. B., 2004, Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers Through Backward Linkages. American Economic Review.

Wendy, D., & Chia, S. Y., 2004, Multinationals and East Asian Integration. International Development Research Center, Canada.

Zarsky, L., 1999, Havens, Halos and Spaghetti: Untangling the Evidence About Foreign Direct Investment and the Environment. Foreign Direct Investment and the Environment.

Zhu, H., Duan, L., Guo, Y., & Yu, K., 2016, The Effects of FDI, Economic Growth and Energy Consumption on Carbon Emissions in ASEAN-5: Evidence from Panel Quantile Regression. Economic Modelling.

PUBLICATIONS

Measuring Carbon Emissions of Foreign Direct Investment in Host Economies
Working Paper No. **WP/2022/086**