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Is production in global value chains (GVCs) sustainable? A review of the empirical evidence on social and environmental sustainability in GVCs[1]

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Abstract

Sustainability in global value chains (GVCs) hinges on the interplay between specialisation, scale, and efficiency effects. This paper reviews different strands of literature which provide evidence on these channels. The evidence that I collect suggests that the sustainability impacts of GVCs are ambiguous. By allowing firms to specialise through the offshoring of relatively more polluting production activities, GVCs are associated to sizeable amounts of carbon leakage. Insofar as firms expand following entry in foreign markets, environmental impacts may also increase. Yet at the same time, participation in GVCs makes firms more energy and emission efficient than their domestic peers through a variety of mechanisms. Thus, GVCs also contribute to dampen emission growth. In terms of social sustainability, GVCs are associated with an income premium for workers and producers alike, although these benefits are not equally distributed.

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Contents

1. Introduction

A growing form of international industrial organization, global value chains (GVCs) entail the fragmentation of production processes across national borders.[2] Exporters as well as multinational enterprises (MNEs) and their affiliates source parts and components in one country, process them in another, and ship them out for final consumption in yet another jurisdiction. GVC trade has grown rapidly since at least the mid-1990s, driven by technological improvements in transport and logistics as much as by trade liberalization at the global and—increasingly—regional level. According to World Bank (2020) estimates, GVC trade accounted for just under 50 percent of global trade in 2015.

While many economies have benefited from increased participation in GVCs, concerns are growing around the environmental and social impacts of the international fragmentation of production (Wiedmann and Lenzen, 2018). Motivated by incidents such as the 2013 Rana Plaza collapse in Dhaka, Bangladesh, and by the slow progress of climate change mitigation activities worldwide, a consensus is emerging that governments and businesses should act to improve the environmental performance of, and social conditions within GVCs. Many private voluntary initiatives have been launched. Policymakers in the European Union and in other industrialized and emerging economies are also increasingly discussing the introduction of environmental and social due diligence legislation for companies operating globally.

Against this background, this paper provides a review of the evidence on the environmental and social sustainability of trade and production within GVCs. I review recent empirical research in economics that sheds light on these issues. This is a potentially large literature, which I restrict to two main strands. The first is work using environmentally and socially augmented multi-regional input-output (MRIO) models. Over the past decade, MRIO models have been the workhorse models for the analysis of GVCs at the macro level. The second strand I review is firm-level literature.

Macro- and micro-level literature complement each other. MRIO models enable one to quantify the magnitude of CO_2 emissions and other impacts associated with GVCs in the aggregate; identify their broad drivers (consumption, technical change, offshoring); and understand how these impacts are distributed across countries. This is largely descriptive work. By contrast, micro-level work enables one to look at the impacts of GVCs within countries. This literature typically compares agents that participate to GVCs in one form or another with agents that do not and asks how the former perform relative to the latter.

Given the potentially vast amount of micro-level literature which this paper covers, this review does not aim to be comprehensive. I restrict my focus to recent literature using experimental or quasi-experimental methods to control for endogeneity, selection, and other sources of bias

[2] In what follows, I use the term GVCs to refer to a set of closely interrelated concepts, such as global supply chains, cross-country production sharing, and intermediate trade. While there are methodological and disciplinary differences underpinning the use of different terms, all of them tend to refer to the same process.

which might affect the relationship between firm-level behaviour and sustainability. Establishing a credible counterfactual to assess the "true" damage (or lack thereof) associated with GVCs is an important issue in this literature. While I focus primarily on micro-econometric studies, I also draw insights from more qualitative work such as case studies. Throughout the text, I highlight the strengths and limitations of different strands of work.

The evidence I collect can be summarised as follows. In terms of environmental sustainability, GVCs are linked to emission growth through two main channels—scale and specialisation. Insofar as firms expand following entry in foreign markets, environmental impacts may also increase. Specialisation takes place through the offshoring of production activities which were previously performed domestically to locations where the carbon intensity of production is, on average, higher. With traditional trade, firms can source relatively more polluting inputs from abroad. GVCs accelerate these processes and make it possible to offshore a wider variety of production tasks—at a more fine-grained level.

Both macro- and micro-level evidence suggest that offshoring leads to carbon leakage, thus increasing worldwide CO_2 emissions. One of the implications of carbon leakage is that there is a growing divergence between production- and consumption-based approaches to emission accounting. Lower-income economies—which are on the receiving end of offshoring—are generally found to have become net exporters of emissions and other environmental impacts, to cater to consumers in higher-income economies.[3] As a result, higher-income economies appear to have become cleaner over time. Both macro- and micro-level literature suggest that the offshoring of relatively polluting production activities has contributed to dampen the growth of emissions in higher-income countries.

There is consensus, however, that offshoring is not driven by differences in environmental regulation stringency across countries but rather by demand for cheaper or higher-quality inputs. Moreover, both MRIO models and micro-level literature suggest that consumption levels are the main driver of global emissions. Carbon leakage plays an important, but relatively secondary role. Consumption levels are historically higher in high-income economies—and remain so. While demand for cleaner products might be on the rise in these economies, changes in consumption patterns remain unexplored in the strands of literature I review. The rise of China and other emerging economies is found to contribute an increasingly large share of global consumption and, therefore, emissions. The carbon-intensive nature of energy systems in emerging economies compounds the problem.

At the same time, however, GVCs might allow for the faster diffusion of cleaner technology across countries. Micro-level literature highlights that firms engaged in GVCs have lower emission and energy intensities relative to firms that do not engage in GVCs. Insofar as they assume homogeneity in technology and input structures within and across industries, estimates

[3] Consumers include both final goods consumers—such as, for instance, households—and consumers of intermediate and capital goods, i.e. firms.

on the sustainability costs of GVCs arising from MRIO models might therefore be biased upwards. Moreover, there is evidence of a causal relationship running from exporting to environmental performance, although the mechanisms underpinning this relationship remain open to investigation. Evidence on exporters and emissions is largely limited to high-income countries, however, which constitutes an important gap.

Findings on the social sustainability of GVC production are heterogenous. Macro-level evidence on trade-related social impacts is largely inconclusive, due to severe data limitations. Micro-level evidence suggests that participation in GVCs is beneficial for producers and workers in the formal economy. Indicators such as profits, wages, consumption, and working conditions all tend to improve because of engagement in GVCs. The case study literature, however, finds that these outcomes are different for irregular workers and in the lower tiers of value chains. Here, precarious labour arrangements and scarce compliance with standards and regulations seem to be more prevalent, although it is hard to quantify them. This is an issue that remains empirically under-investigated. In the final section of this paper, I highlight the research gaps which emerge from these various strands of literature.

2. Macro-level evidence

The macro-level approach to measuring GVC trade relies on multi-regional input-output (MRIO) tables. MRIO tables are constructed by connecting the national input-output tables of different countries using data on bilateral trade (Johnson, 2017).[4] The World Input-Output Database (WIOD) and EORA are among the most widely used sources of MRIO tables. To study the environmental and social impacts of GVC trade, researchers combine data on the environmental impact of production—in terms of, for instance, greenhouse gas (GHG) emissions[5]—with MRIO tables. This allows the estimation of the environmental and social "content" of a unit of output or value-added, as well as to trace impacts along the value chain according to where output is produced and consumed.[6]

The procedure to estimate the environmental and social impacts embodied in GVC trade using MRIO tables is relatively simple. Since this approach is common across a range of different studies, it is worth describing it in some detail at the beginning. The result is a multi-country, multi-sector matrix resembling a chessboard. In this matrix, rows represent the social or environmental impacts that country-sectors "send out" to other country-sectors for intermediate

[4] In an MRIO table, rows indicate the use of gross output from each industry in each country. Rows comprise of two main components. The first is intermediate use by domestic industries as well as industries in other countries. The second is information on final demand, which is again split between demand for final products from domestic and foreign sources. Columns, on the other hand, provide information on the amounts of intermediates needed to produce gross output. The column sum gives the sum of the domestic and foreign production of intermediates that are used in the production of output in each industry and country. Combining this sum with the sum of value added generated in each industry and country gives the value of gross output.

[5] Anthropogenic GHG emissions include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

[6] It is common to speak of the environmental or emission "content" of trade, or—which is equivalent—to refer to emissions as being "embodied" in trade. It is worth clarifying that emissions are of course not a physical part of any traded product, but rather they are associated with the production of that product (Meng et al., 2018).

use or final consumption, and the columns the impacts that country-sectors "receive" from other country-sectors further upstream, again for intermediate use or final consumption (see, for instance, de Vries and Ferrarini, 2017; Meng et al., 2018; Cadarso et al., 2018; López et al., 2019; García-Alaminos et al., 2020).

The first step in the creation of this matrix is constructing a diagonalised vector, $\hat{e}$, capturing the social and environmental impacts of each industry in each country. Impacts can be proxied by an industry's total emissions, or the intensity of emissions (that is, emissions over gross output). This vector is then multiplied to a Leontief inverse matrix, L, and to a vector of final demand requirements y, resulting in a $\hat{e}Ly$ matrix.[7] Knowing the emissions associated with a unit of output, and the output that is required by a given level of final demand, it is possible to estimate total impacts throughout the world economy.

Using socially- and environmentally augmented MRIO (henceforth, SA- and EA-MRIO respectively) tables, one can therefore attribute impacts to the countries and industries which are responsible for them. There are two main approaches here. Summing the $\hat{e}Ly$ matrix by rows yields the total environmental impacts that a specific sector in a specific country generates. This is referred to as production-based or territorial accounting (PBA) because environmental impacts are allocated to the country in which they occur—irrespective of whether production is for domestic consumption or for export.

Summing the matrix by columns provides the sum of the environmental impacts which, despite being generated by different producers across the globe, are ultimately linked to a specific country and industry's final demand. This is referred to as consumption-based accounting (CBA), or "footprinting". CBA is equivalent to PBA minus the export of domestically produced emissions embodied in exports, and plus the import of emissions produced abroad and embodied in intermediate and final goods that enter domestic supply chains and consumption systems.

Production-based accounting relates to the criteria adopted within the framework of the Kyoto Protocol. Criticism of PBA is based on two interrelated observations. The first concerns the issue of responsibility. The disassociation between production and consumption which accompanies GVCs means that the impacts induced by consumption in one location often occur somewhere else. It has been estimated that between 10 and 70 percent of social and environmental impacts gets displaced geographically through international trade (Wiedmann and Lenzen, 2018). Secondly, PBA only captures the direct impacts of production. In environmental terms, these correspond to Scope 1 and 2 emissions as defined by the GHG Protocol.[8] All indirect impacts, such as those associated with trade, are not included.

[7] Each coefficient in the Leontief matrix yields the direct and indirect effects on output in one industry required by the production of a unit of output in another industry.

[8] Scope 1 and Scope 2 emissions include, respectively, the direct emissions generated in production and the emissions generated as a result of the use of purchased energy.

CBA helps overcoming this difficulty, as it attributes responsibility to the countries where consumption occurs. This is because CBA considers indirect impacts, such as those associated to trade. Indirect emissions fall within Scope 3 emissions of the GHG Protocol. Differences between the two perspectives can be marked, especially for those countries, such as the US or EU countries, where production activities have been offshored in recent years. CBA is not exempt of criticism, with some authors arguing that any accounting method tends to neglect the equilibrium implications of production. Not importing a unit of embodied emissions, for instance, does not necessarily mean that those emissions will not be released into the atmosphere (Jakob and Marschinski, 2013).

2.1 GVCs and environmental sustainability: evidence from EA-MRIO tables

2.1.1 Finding 1: GVCs are associated with carbon leakage, but there is no consensus on the magnitude of leakage

There is consensus in the literature that cross-border production sharing is associated with an increase in total environmental impacts worldwide because of carbon leakage. Carbon leakage occurs when firms choose to offshore part of their production activities to countries with lower environmental standards (Malik and Lan, 2016). The international shipment underpinning GVCs also has environmental impacts, although these are not explicitly quantified in CBA analyses.[9] Using WIOD data, Meng et al. (2018) estimate that due to carbon leakage, the environmental cost—in terms of emission volumes over value added—of producing one unit of GDP through international trade was 1.4 times higher than that through domestic production linkages in 1995, and 1.8 times higher in 2009 (Meng et al., 2018).

The actual magnitude of carbon leakage, however, suggests that it is not the main driver of emission growth.[10] When they decompose the increase in embodied CO_2 emissions at the global level during the 1995-2008 period into its main drivers using a set of structural decomposition equations, de Vries and Ferrarini (2017) estimate that only 9 percent of additional emissions are due to MNEs relocating the production of final goods abroad. Hoekstra et al. (2016) employ a different structural decomposition method, which allows them to attribute changes in CO_2 emissions to the offshoring of intermediate goods production. They estimate that offshoring from high- to low-wage economies may have contributed up to 18 percent of the global growth in CO_2 emissions from 1995 to 2007.

2.1.2 Finding 2: Growing consumption levels drive emissions embodied in trade

While carbon leakage plays a role in emission growth, this literature also argues that the lion's share of emission growth is in fact driven by the growth of global consumption levels. This is

[9] By contrast, in PBA emissions arising from international shipping and aviation are typically allocated to their "origin" country.
[10] Another question is whether carbon leakage is driven by changes in environmental policy across countries. Evidence that it is would point to "strong" carbon leakage effects (Hoekstra et al., 2016). Since aggregate data makes it difficult to distinguish between the two, evidence reported in this section should be considered as evidence of "weak" carbon leakage. I return to this distinction in Section 3.1.

the second stylized fact emerging from the EA-MRIO literature. According to de Vries and Ferrarini (2017), for instance, were it not for technological improvements making production more CO_2 efficient, the growth of consumption would have made emissions grow by twice as much between 1995 and 2008. Estimates with similar magnitude are reported in Hoekstra et al. (2016).

Consumption levels have grown in developing and developed countries alike, with the growth of domestic consumption in fast-growing economies such as China accounting for an increasing share of consumption-induced emissions (Hoekstra et al., 2016; de Vries and Ferrarini, 2017; Meng et al., 2018). In the case of China, de Vries and Ferrarini (2017) estimate that only about 15 percent of the country's territorial emissions are embodied in trade, with the remainder being associated with domestic consumption. Consumption-based emissions for China have increased from 4883 to 8074 Mt CO_2 between 1995 and 2008—a growth of over 65 percent in two decades. By contrast, consumption-based emissions have grown by just over 15 percent in both the EU and the US over the same period (de Vries and Ferrarini, 2017).

2.1.3 Finding 3: Higher-income economies are net importers of environmental impacts, and lower-income economies net exporters

There is a consensus that high-income countries are net importers of trade-embodied GHG emissions (Xu and Dietzenbacher, 2014; de Vries and Ferrarini, 2017; Wiedmann and Lenzen, 2018).[11] De Vries and Ferrarini (2017), for instance, estimate that in 2008, the 15 richest European Union economies imported 926 Mega tons (Mt) CO_2 whereas China exported over 1350 Mt CO_2. The same EU economies are estimated to have generated 3431 Mt CO_2 in the same year, that is, one fourth of total European emissions are imported.[12] As a result of these transfers, territorial emissions grew by a mere 1.8 and 4.8 percent in the EU and US respectively in the 1995-2008 period.

Similarly, Fernandez-Amador et al. (2020) suggest that high-income economies remain net importers of embodied methane (CH_4) emissions.[13] High-income economies account for 56 percent of global imports of trade-embodied CH_4 emissions, a share which has remained stable

[11] Impacts are not limited to emissions. In their recent review of the "footprinting" literature, Wiedmann and Lenzen (2018) reflect on the growing span of environmental issues covered by CBA studies. GHG emissions and air pollution, loss of biodiversity, land use, and water have all featured in the literature—alongside studies considering the nexus between different natural resources. There is also work linking CO_2 emissions to deforestation within countries as a result of the global consumption of specific agricultural commodities (see, for instance, Karstensen et al., 2013 on the case of cattle and soybean production for export in Brazil)

[12] To put these magnitudes in perspective, consider that 926 Mt CO_2 correspond to the emissions that would be generated by driving 3.6 billion kilometres in an average car, according to the EPA's greenhouse equivalencies calculator.

[13] Methane is disproportionally generated in livestock breeding and other agricultural and extractive activities rather than in manufacturing. From a CBA perspective, it can be associated to the final consumption of processed food imports and other industrial products. To study methane emissions, Fernandez-Amador et al. (2020) match emission data from EDGAR (Emission Database for Global Atmospheric Research) and FAOSTAT to trade data from the Global Trade Analysis Project (GTAP) database

between 1997 and 2008. By contrast, developing and emerging economies such as China, India, and Brazil export more embodied emissions than they import.

An important share of imported emissions can be linked to the trade in intermediates that underpins GVCs. This share tends to be higher for internationally integrated economies. Employing a backward linkage decomposition, Meng et al. (2018) estimate that of the total emissions embodied in the output produced in Germany in 2009, over 35 percent was foreign in origin and linked to the sourcing of intermediate inputs from abroad. This share was 10 percent for China.[14] The level of imported emissions also depends on the energy used in upstream production. China's reliance on coal drives up not only its own territorial emissions but also the emissions of countries importing its inputs for further processing (Meng et al., 2018).

While these studies look at production- and consumption-based estimates at the global level, work at the regional level paints a similar picture. In their study of the footprints of consumption within the Asia-Pacific (APAC) region, Yang et al. (2020) find that final demand in richer APAC countries, such as Australia, Japan, and South Korea, tends to be satisfied by imports of embodied GHG emissions, energy, blue water, and fine particles ($PM_{2.5}$) sourced in poorer APAC countries. Of the region's final consumption of water embodied in traded goods, for instance, 80 percent was associated with exports from India and other lower-income APAC economies in 2015. Rivera-Basques et al. (2021) provides evidence on the displacement of environmental impacts from high- to lower-income economies within Latin America (see Table 1).[15]

[14] From the perspective of a country or industry, this perspective is equivalent to decomposing each unit of embodied emissions in its domestic and foreign component.

[15] Complementing work on global and regional MRIO study is a strand of literature focusing on the footprints of MNEs and their affiliates. López et al. (2019) estimate that in 2009, production by US MNEs accounted for 9.8 and 8.6 percent of the US' producer and consumer footprint, respectively. To study MNEs' footprints, they weight information on the value-added share of US MNE activity in each industry and country—extracted from the US Bureau of Economic Analysis (BEA) database—over total value-added. Ortiz et al. (2020) provide evidence for MNEs operating within the EU.

Table 1 – Overview of the macro-level literature on the environmental impacts of GVC trade

Study	Data sources	Methodology	Main indicator	Time coverage	Regional coverage	Main findings
Xu and Dietzenbacher (2014), *Ecological Economics*	WIOD	• EA-MRIO model • Structural decomposition analysis	CO_2 emissions	1995-2007	Global	• Emissions embodied in trade were equal to 33% of global emissions from production in 2007, up from 24% in 1995
Hoekstra et al. (2016), *Economic Systems Research*	WIOD	• EA-MRIO • Structural decomposition analysis	CO_2 emissions	1995-2007	Global	• Evidence of "weak" carbon leakage due to intermediate offshoring • Carbon leakage accounts for 18% of total emission growth during 1995-2007
De Vries and Ferrarini (2017), *Ecological Economics*	WIOD	• EA-MRIO model • Structural decomposition analysis • CBA and PBA	CO_2 emissions	1995-2008	Global	• Of total emission growth during 1995-2008, >9% is due to offshoring (carbon leakage) • 23% of China's territorial emissions are due to production for foreign consumption
Meng et al. (2018), *Energy Economics*	WIOD	• EA-MRIO model • CBA and PBA vs input-output decompositions	CO_2 emissions	1995-2009	Global	• Estimates CO_2 cost of producing one unit of GDP via trade with developing economies to be 1.8 times higher than that through domestic production for developed economies, due to differences in carbon intensity across borders
Fernández-Amador et al. (2020), *Ecological Economics*	GTAP, EDGAR, FAO	• EA-MRIO • Decomposition analysis • CBA and PBA	CH_4 emissions	1997-2014	Global	• CH_4 emissions embodied in trade increased by 8% more than domestic emissions during 1997–2014 • Higher (lower) income economies are net importers (exporters) of embodied CH_4
López et al. (2019), *Nature Communications*	WIOD, BEA	• EA-MRIO • CBA, PBA, producer footprint	CO_2 emissions	2009	Global	• Estimates that if US-MNEs abroad were a country, it would be 12th top emitter globally
Yang et al. (2020), *Nature Communications*	EXIOBASE 3.6	• EA- and SA-MRIO model • CBA	Nexus study	1995-2015	Asia-Pacific	• Within APAC region, environmental impacts are displaced from richer to poorer countries through trade
Ortiz et al. (2020), J*ournal of Industrial Ecology*	EORA, Eurostat	• EA-MRIO • CBA, PBA, producer footprint	CO_2 emissions	2015	European Union	• MNEs' foreign affiliates account for 17% of total EU carbon footprint
Rivera-Basques et al. (2021), *Ecological Economics*	EORA	• EA-MRIO • CBA	Nexus study	1990-2015	Latin America, Global	• According to most indicators, LA shows unequal ecological exchange with richer economies • Economies integrated within GVCs (Mexico, Brazil) are net importers of CO_2 emissions

2.2 The social impacts of GVCs: evidence from socially augmented multi-regional input-output (MRIO) tables

The macro-level literature on the social impact of GVC trade also relies on MRIO tables. The only notable difference with EA-MRIO models is that the vector of impacts which these studies use to construct measures of trade-embodied impacts includes social, rather than environmental indicators. The literature has looked at a number of themes, including the health and safety of workers, with particular attention paid to occupational injuries (Alsamawi et al., 2017; García-Alaminos et al., 2020); the prevalence of child labour (Alsamawi et al., 2019); as well as the use of forced labour and human trafficking in production systems (Alsamawi et al., 2019; García-Alaminos et al., 2020) (see Table 2).

The availability and reliability of data constitutes an important limitation for this literature. As a result, the SA-MRIO literature is much smaller relative to literature concerned with the environmental costs of GVC production. Cross-country data on some indicators, such as working conditions, does exist but its coverage across time and space is haphazard. Most macro-level research tends to rely on significant data imputation, interpolation, and aggregation to deal with missing values. Data on other indicators, particularly illegal activities such as child labour or trafficking, can only be obtained from surveys run in specific regions and time periods, requiring widespread imputation. To complicate matters, social violations tend to be more prevalent in contexts where data availability is poorer.

2.2.1 Finding 4: Trade-embodied social impacts are more prevalent in low-income countries, but they have declined over time

There is insufficient evidence to support the notion that GVC trade is associated with worsening social conditions in participating countries. What I do find is that higher-income economies tend to import social impacts and that the opposite holds for lower-income countries, and that these impacts are concentrated in certain industries and countries.

Alsamawi et al. (2017) build a dataset of trade-embodied social impacts by merging EORA with ILO and other data sources on occupational-related accidents.[16] They estimate that each year, trade is associated with approximately 46,000 fatal injuries. Over half of these occur in the agricultural sectors of least developed countries (LDCs). In subsequent work using OECD TiVA data, Alsamawi et al. (2019) focus on child labour and human trafficking. They find that to the extent that social violations are embodied in trade, they are more prevalent in lower-income economies. Since these are illegal activities, however, data limitations are severe.[17]

[16] The ILO provides data on occupational injuries. Additional sources of data derive from the ASEAN Occupational Safety and Health Network (ASEAN-OSHNET) and the State Administration of Work Safety (SAWS) databases. They report data gaps, including missing values for given time periods and the unavailability of sectoral breakdowns for certain indicators.

[17] For child labour, of 65 nationally representative surveys which were originally run with the support of the ILO, UNICEF, and USAID, only 30 are reported to have been released with information on sectoral shares.

In general, then, the highest incidence of social impacts tends to be found in LDCs, where working conditions—particularly in agriculture—are likely to be generally poor. Insofar as these countries export, they will drive up trade-related social impacts given how the MRIO analysis is set up. I find no evidence, however, to support the notion that these impacts are driven by participation in GVCs. Rather, there is some evidence that trade-embodied social impacts have, in fact, declined over the course of the past two decades: Alsamawi et al. (2017) estimate that trade-embodied occupational injuries have decreased over time—from 28 to 26 percent of total injuries between 1990 and 2010. This trend may be driven either by improvements within traded sectors, or by trade in sectors with better labour conditions, such as manufacturing, increasing faster relative to other sectors where conditions are poorer.

Table 2 – Overview of the macro-level literature on the social impacts of GVC trade

Study	Data sources	Methodology	Main indicator	Time coverage	Regional coverage	Main findings
Alsamawi et al. (2017), *Journal Cleaner Prod*	EORA, ILO, ASEAN-OSHNET, Others	• SA-MRIO	Fatal and non-fatal occupational injuries	1990-2010	Global	• High- (low-) income countries are net importers (exporters) of trade-embodied social impacts • Trade-embodied injuries declined from 28 to 26 percent of the total between 1990 and 2010
Alsamawi et al. (2019), ILO technical report	OECD TiVA, ILO surveys	• SA-MRIO • CBA	Child labour, forced labour, human trafficking	2015	Global	• Estimates that 28 to 43 percent of child labour is concentrated in mining and agriculture
García-Alaminos et al. (2020), *Econ Sys Research*	WIOD, ILO	• SA-MRIO • CBA, PBA, producer footprint	Forced labour, occupational injuries	2009-2013	Global	• If US-MNEs abroad were a country, it would be 11th country with largest social impacts

2.3 Discussion

The MRIO literature provides evidence of "weak" carbon leakage, resulting from the offshoring of production activities from countries with higher per capita incomes and lower emission intensities, to countries with lower income and higher intensities (Hoekstra et al., 2016; de Vries and Ferrarini, 2017; Meng et al., 2018). This observation is corroborated by micro-level studies (see Section 3.1 below). While estimates on the magnitude of leakage differ according to whether studies focus on the offshoring of final or intermediate goods production,

Proportionality is therefore assumed for countries and industries for which no estimates are available. In the case of forced labour, Alsamawi et al. (2019) rely on the 2016 ILO global estimates on forced labour and victim case data from the International Organization for Migration (IOM), which are then distributed by country, region, and sector assuming proportionality between the number of estimated cases, on the one hand, and population and employment on the other.

there is consensus that offshoring is an important if not the primary driver of emission growth worldwide.

Indeed, trade-related environmental impacts appear to be driven primarily by the growth in consumption levels worldwide. Insofar as GVCs make production more efficient and products cheaper, one might argue that they do contribute, at least indirectly, to increase consumption-driven pollution. The difficulty of disentangling the role of trade from that of technology, however, makes it unlikely that this issue can be settled firmly. At the same time, it is possible that changes in consumption patterns play an important role in curbing emission growth. If consumers were to switch to more environmentally friendly goods, trade-related environmental impacts would also decrease. While high-income economies have historically driven global consumption levels, China and other emerging economies have also started playing an important role. Environmental costs, however, remain unevenly distributed.

While GVCs are associated with environmental externalities, there is also evidence suggesting that technical change in both high- and lower-income economies plays an important—if insufficient—role in dampening emissions growth (see, for instance, Hoekstra et al., 2016; de Vries and Ferrarini, 2017). These studies do not observe technical change directly. Therefore, there remains an open question regarding the role of GVCs in making production less emission-intensive—by, for instance, improving resource efficiency, or by stimulating the diffusion of cleaner technologies. Some of the micro-level literature which I review in Section 3.1 below points in this direction, but more research into this topic would be required.

It is worth stressing that input-output models have two important limitations, which complicate efforts at estimating the magnitude of sustainability impacts within GVCs. The first relates to the assumption, built into MRIO tables, that all firms in an industry rely on the same technologies and input structures (Timmer et al., 2015). Yet micro-level evidence suggests otherwise. Marked differences exist in terms of technological endowments, capabilities, and import structures, between traders and firms supplying the domestic market only. If firms active within GVCs are more resource-efficient than domestic firms, MRIO models over-estimate the environmental impacts of GVC production. I return to these issues in Section 3.

A second shortcoming of EA-MRIO models relates to the absence of fine-grained geographical data. Yet environmental and social impacts are likely to be localised. There is evidence, for instance, that the increased air pollution associated with international trade impacts health—with effects which are likely to be felt more heavily in affected locations than elsewhere (Wiedmann and Lenzen, 2018). One answer to this challenge consists of mapping sub-national to global input-output tables (Y. Yang et al., 2020). Another is constructing matrices with spatial data on the production and consumption of specific resources and linking them using bilateral trade data (Godar et al., 2015).[18]

3. Micro-level evidence

Measuring GVC participation at the micro level, that is, at the level of the firm, production plant, or farm, is challenging. A first challenge stems from differences in the organization of GVCs across sectors. What exactly makes an agent a GVC participant depends on the sector one is studying. In manufacturing, exporters, importers (particularly importers of intermediates), domestic suppliers to MNEs, and foreign firms, are all typically associated to GVCs in the literature. In agriculture, smallholders with an international certification acting as suppliers to exporters and processors, and export-oriented farms supplying to large buyers such as supermarkets, can be considered part of a GVC.[19] Similarly, industrial mines for the extraction of fuels and minerals which are exported and then enter production processes further downstream are also considered part of GVCs.[20]

A related challenge concerns the distinction between agents who directly participate to GVCs, such as exporters; and lower-tier firms who supply to exporters and are therefore part of the domestic sections of value chains. In agriculture, certification helps to discriminate—whether they directly export or not, certified farmers tend to be considered part of GVCs. The distinction is blurrier in manufacturing. Data availability compounds the challenge. Tracing GVCs at the micro-level would require detailed information on firm-to-firm business transactions. Yet most administrative firm-level databases providing information on international trade—such as data collected and maintained by customs or tax authorities—do not include data on firm-to-firm transactions.[21] As for lower-tier suppliers, in developing economies these firms may be active in the informal economy, making them even more difficult to trace as they do not appear in administrative datasets. To derive insights on these agents, I draw from qualitative literature such as fieldwork and case studies.

A note on measurement. In terms of environmental sustainability, different strands of literature rely on different indicators. Literature on manufacturing firms focuses on efficiency measures.

[18] Godar et al. (2015) use data on a country's imports and exports to allocate the environmental effects associated with the domestic production of a commodity—in this case, soybeans in Brazil—to domestic and foreign sources of production and consumption. Domestic consumption is allocated to different hubs proportionally to their population and industrial capacity. The allocation is inversely proportional to transportation costs. Customs data then allows for the identification of domestic production locations—proxied by trade facilities such as airports—and for the allocation of exports to foreign consumers.
[19] The distinction between smallholder producers and wage employees in larger, "agribusiness" farms is purely analytical. Smallholder farms may be relatively large, use modern technologies, and employ salaried workers (for a review of some of these issues, see Oya, 2010, and 2011).
[20] Another stream of literature concerns the socio-economic and environmental impacts associated with small-scale, artisanal mining. Since it is difficult to ascertain whether small-scale miners act as exporters or as suppliers to exporters or rather operate on domestic markets, I chose not to include this literature in the present review. For discussions of this sector, see Hilson (2002, 2009) and Bazillier and Girard (2020).
[21] Recently, a number of studies have begun exploring data on firm-to-firm transactions (see Alfaro-Urena et al., 2019 who use data from Costa Rica; and Dhyne et al., 2020 who use Belgian data).

These studies consider emission intensity, that is, the quantity of emitted pollution per unit of output (Cui et al., 2016; Cherniwchan, 2017; Forslid et al., 2018; Dussaux et al., 2020); and energy intensity, in terms of energy use over output (Giuliani et al., 2017; Imbruno and Ketterer, 2018) or over sales (Batrakova and Davies, 2012). Literature on farms and mines focuses on environmental externalities, particularly deforestation, and its impacts on biodiversity and carbon loss (Brandi, 2017; Qaim et al., 2020), and land and soil pollution (Akpalu and Normanyo, 2017; Pokorny et al., 2019). The use of different indicators, and the focus on measures of efficiency as opposed to production externalities in different strands of work mean that direct comparisons across the literature are not straightforward.

3.1 Micro-level evidence: the environmental impacts of GVC production

3.1.1 Finding 5: Exporters have lower emission- and energy intensities relative to non-exporters

A number of studies has looked at the relationship between the exporting status of firms and their environmental performance. Holladay (2016) asks whether exporting is linked to the emission of toxic pollutants for a panel of US manufacturing plants over the 1990-2016 period. His dependent variable is a composite score of harmful pollutants compiled by the United States Environmental Protection Agency (EPA).[22] The data collected, however, is reported by plants themselves. This might introduce measurement errors. Holladay finds that exporters pollute 10 percent less, on average, relative to non-exporters, controlling for a host of firm-, industry-, and state-level variables. When breaking down the sample by industry, however, results appear heterogenous: in four industries, exporters appear to be *more* polluting than non-exporters. While Holladay (2016) suggests that exporters are likely to display better environmental performance because they are more productive, due to data limitations he does not provide evidence on productivity.

Using EPA and NETS data for the years 2002, 2005, and 2008, Cui et al. (2016) are able to compute establishment-level measures of total factor productivity (TFP) for the US economy. Controlling for productivity, they find that exporting is still associated with a large reduction in plant-level emission intensity—between 26 and 29.5 percent, depending on the specification.[23] This suggests that exporting may influence environmental performance independently of productivity.[24] When including a control for firm size, the significance on the exporting status coefficient disappears, suggesting that the relationship between exporting and environmental performance is driven by a market size effect. Exporting enables firms to access

[22] The composite score weights a plant's emissions by their pollution and epidemiological impact. Establishment-level data comes from the US National Establishment Time Series (NETS) database.
[23] They focus on SO_2, CO, O_3, and total suspended particulates (TSPs) emissions.
[24] This is not to say that productivity does not influence environmental performance. On the contrary, studies controlling for productivity consistently find that more productive firms display a better environmental performance (Batrakova and Davies, 2012; Cui et al., 2016; Forslid et al., 2018). Rather, the question is whether exporting, conditional on productivity, also has a statistically discernible impact on environmental performance—and if so, why.

a larger pool of consumers and thus increase their production volume, kicking economies of scale into gear—provided emissions are proportional to input use (Cui et al., 2016). Larger firms might also be better able to cope with the fixed costs involved in in abatement and pollution control activities.

Forslid et al. (2018) provide a rationalization of the market size explanation. In a Melitz-type model with heterogenous firms and intra-industry trade, they show that firms' abatement decisions depend on the volume of production, since the achievement of a larger scale allows firms to spread the fixed costs associated with abatement and pollution control across more units. Using Swedish firm-level data for the 2004-2011 period, they find that exporters are less CO_2 intensive than their non-exporting counterparts, by approximately 13 percent. They also find that exporters tend to invest more in abatement compared to non-exporters (Forslid et al., 2018). While there is evidence that exporters are "cleaner", these studies do not directly address the causal direction between exporting and environmental performance. Does exporting cause an improvement in environmental performance? Or do "cleaner" firms—which also happen to be larger and more productive—self-select into exporting?

To answer this question Batrakova and Davies (2012) focus on first-time exporters, rather than on continuous exporters as in the studies reviewed so far. Their identification strategy relies on matching firms that export for the first time to a group of never-exporters which have similar characteristics. They then estimate the effect of exporting on the first group, using a difference-in-difference (DID) strategy to control for time-invariant unobserved differences in firm-level characteristics. Their main outcome of interest, however, is not emissions but rather energy efficiency, defined as energy use over total turnover. They find that exporting has heterogenous effects across firms. Highly energy-intensive firms do become more efficient after exporting relative to firms who, despite having similar characteristics, do not enter export markets. In the first year after having started to export, they decrease their energy intensity by 26 percent relative to the last pre-export year. Low-energy intensive firms, by contrast, see their energy intensity increase after exporting—an increase of 20 percent on the previous year (Batrakova and Davies, 2012).[25]

Evidence on the environmental impacts associated with agricultural and mining GVCs is more mixed. This literature finds that agricultural production for export tends to have environmental externalities. Qaim et al. (2020) review evidence on the impacts of the expansion of smallholder cultivation for export on biodiversity and environmental indicators in the Jambi province of Sumatra, one of the hotspots of the Indonesian palm oil boom.[26] Comparing plots

[25] Pei et al. (2020) also use PSM to construct a "control" and a "treatment" group among Chinese exporters in 2007. They find that a one percent increase in export intensity—defined as export value over output—is associated with a 0.03 percent decrease in SO_2 emission intensity. That the differences in the means of key covariates, such as productivity, between the two groups remain significant after matching casts some doubt on the empirical exercise. Details on matching are reported in the supplementary material (Pei et al., 2020).

[26] Qaim et al. (2020) report that oil palm production accounted for 16 percent of total deforestation in Indonesia, and 47 percent of deforestation in Malaysia, over the past 40 years.

of protected, non-cultivated rainforest with land under palm oil cultivation, they observe large differences in terms of species abundance, average temperatures, and ecosystem functions. They also find large carbon losses from the expansion of palm oil cultivation—the conversion of forested to cultivated land is associated to carbon losses of 61 percent on average (Qaim et al., 2020). Naylor et al. (2019) report similar findings.

Giuliani et al. (2017) and Brandi (2017) focus on the environmental implications of certification. Giuliani et al. (2017) focus on the coffee value chain using a survey of 575 certified and non-certified farms across Latin America. They find an increase of approximately 26 percent of the sample standard deviation for their environmental indicator variable for certified relative to non-certified farms.[27] By contrast in her qualitative study of a smallholder certification programme aimed within the palm oil value chain in Indonesia, Brandi (2017) reports that certification leads farmers to expand cultivation and increase profits, but since expansion can occur on non-certified plots there are important trade-offs between social and environmental dimensions. The use of an unrepresentative sample of 196 smallholders, however, limits the generalizability of her findings.

Regarding mining GVCs, there is consensus that extractive activities have substantial environmental externalities. Pokorny et al. (2019) survey households across six district—two of which host large-scale industrial mining operations—in two different provinces in Burkina Faso. They find that gold mining projects in Burkina Faso are associated with soil pollution in nearby areas, and the accumulation of toxic solution in sewage lagoons. Kumah (2006) documents similar externalities resulting from gold mining operations in Ghana.[28] In their meta-analysis of the impacts of unconventional natural gas extraction (UNG) on communities located around extraction sites, Buse et al. (2019) report finding marked environmental impacts in terms of water and air quality, soil and agricultural impacts, and issues related to water supply.[29]

3.1.2 Finding 6: Importers of intermediates have a stronger environmental performance—but this may be driven by the offshoring of dirty inputs

Just as work on exporting and the environment points to environmental gains for exporters, literature on importers suggests that the import of intermediates is associated to environmental performance improvements.[30] The mechanisms linking imported intermediates to emissions

[27] Their environmental conduct indicator includes information on farms' consumption of resources and electricity, use of fertilizers and pesticides, recycling patterns, and environmental management.

[28] These environmental externalities have repercussions on human health. Akpalu and Normanyo (2017) focus on the healthcare expenditures of households living near a gold mining site in Ghana, where exposure to pollutants such as nitrogen dioxide (NO_2) is common. They estimate a hedonic model suggesting that a 1 percent decrease in households' distance from a mining site is associated with a 0.12 percent increase in healthcare expenditures.

[29] UNG includes shale gas and tight gas, which require hydraulic fracturing (or fracking), to be extracted.

[30] The same literature, however, finds that importing, in general, does not necessarily bring about environmental improvements at a more aggregate level. Both Holladay (2016) and Cherniwchan (2017) find that an increase in import competition is associated with increases in harmful pollution and a small increase in PM_{10} emissions,

and energy use, however, remain contested. One strand of literature focuses on productivity. Insofar as it fosters greater complementarities between inputs, access to intermediates of different quality and variety makes firms more productive. Productivity increases, in turn, help firms producing the same output with lower amounts of input factors—including, for instance, energy.

Imbruno and Ketterer (2018) study imported intermediates and firms' energy efficiency (energy over output), using data on the product varieties imported by Indonesian firms between 1991 and 2005. Their strategy to identify the causal effect of importing is similar to that implemented by Batrakova and Davies (2012). Using propensity score matching (PSM), they construct two groups composed of firms with similar observable characteristics, bar one—the first group includes new importers, the second never-importers. A DID strategy is then used to address unobservable characteristics. They find that relative to never-importers with similar characteristics, new-importers of intermediate inputs experience energy efficiency gains of up to 12.7 percent by the third year after importing starts. They attribute these effects to the productivity gains resulting from the use of new varieties of intermediates in production (Imbruno and Ketterer, 2018).

That imported intermediates should lead to environmental performance improvements can have another explanation, however. This relationship might simply be due to the offshoring of polluting inputs. In this case, importing is linked to environmental improvements—but only because emission-generating activities are offshored. Cherniwchan (2017), for instance, also finds that intermediate inputs are associated with a reduction in pollutant emissions by looking at US manufacturing establishments following the entry in force of NAFTA. To identify the causal effects of trade liberalization on environmental performance, his study takes advantage of variations in trade costs due to the geographical location of manufacturing plants.[31] He finds that one percentage point reduction in US tariffs on Mexican intermediate imports is associated with reductions in domestic emissions.

The mechanism he highlights is that firms may choose to offshore relatively more polluting production tasks to other countries, thus reducing their emissions. When disaggregating intermediate imports into relatively "clean" and "dirty" he finds that the latter group is associated with a larger—5.8 percent—and more significant reduction in CO_2 emissions compared to the import of all intermediates (Cherniwchan, 2017). Similarly, Dusseaux et al. (2020) find that the import of embodied imported emissions increases the emission efficiency of French manufacturing firms during the 1997-2014 period. They measure imported emissions by weighting industry-level data on CO_2 intensity from WIOD and IEA with customs data on

respectively. Cherniwchan et al. (2017) suggest these results might be driven by changes in abatement and pollution control investments by firms which are forced to downsize as a result of foreign competition in their home markets.

[31] The idea here is that a reduction in tariffs on imports from Mexico will only affect those plants which are located in US states where trade costs are already low, with plants in other geographies acting as a counterfactual.

the actual level of imports French firms source from foreign industries.[32] They also find that two-way traders—exporters who also import—tend to experience larger reductions in their emissions, especially when large, corroborating existing evidence on the environmental performance of exporters (Dussaux et al., 2020).

The two explanations are not necessarily in contrast with each other. A possibility is that both mechanisms are at play, with the variety-productivity channel being particularly relevant in a developing country context following an episode of liberalization, such as Indonesia, and offshoring effects being more relevant in industrialized economies—a finding which finds some resonance with macro-level literature reviewed in Section 2.1. In industrialized economies, firms might offshore the production of dirtier inputs in response to more stringent environmental regulations. Dusseaux et al. (2020), however, suggest that it may be broader economic considerations, rather than changes in regulation, which drives the offshoring of pollution. They find that energy prices—a proxy for environmental policy—are not related to increases in imported emissions.[33]

3.1.3 Finding 7: Foreign investment is associated with improvements in environmental performance

The final piece of evidence I review concerns foreign investment. The relationship between FDI and the environment, particularly at the aggregate level, remains the subject of significant debate (see Cole et al., 2017, for a recent review of the literature). In a recent study, however, Brucal et al. (2019) find evidence that foreign investors do bring about environmental gains in newly acquired establishments. They look at foreign acquisitions—rather than greenfield investments—of over 10 percent of existing plants in Indonesia for the 1983-2001 period and study their effects on CO_2 emissions and energy consumption.

Brucal et al. (2019) have data on plant-level expenditures on, and physical usage of different energy inputs such as fuel, lubricants, and electricity. They match each of 210 new acquisitions to a control plant, and find, within a DID framework, that acquired plants experience reductions in energy intensity of about 30 percent two years after changing ownership relative to non-acquired plants with similar characteristics. They also look at divestments and find that these tend to increase the intensity of energy use (Brucal et al., 2019). Since their results hold when focusing on plants experiencing little change in their product mix and levels, they suggest that foreign investment is linked to stronger environmental performance through the introduction of newer technology and management practices rather than through shifts to cleaner products.

[32] While the use of WIOD data enables them to capture indirect, as well as direct emissions associated with trade, it also forces them, much like in MRIO work, to assume that all products of a given category imported from a given country-sector has a uniform level of emissions.

[33] Literature on agricultural and mining GVCs does not discuss the relationship between importing and environmental impacts. These activities are located upstream and do not necessarily require the import of intermediate inputs.

That foreign firms can promote knowledge transfer within GVCs is an important theme in a vast and multidisciplinary case study literature. With regard to environmental technology and standards, De Marchi et al. (2013), Khattak (2015), and Aron and Molina (2020) find that foreign buyers—in the Italian furniture industry, in the Sri Lankan textile sector, and in the Peruvian mining industry respectively—are instrumental in the adoption of cleaner technologies and environmental certifications such as the ISO 14001.[34] Similar evidence is reported in UNCTAD (2010) for the Mexican automotive sector. Interviews with first- and second-tier suppliers to Volkswagen describe how the carmaker had facilitated the diffusion of environmental certifications. These studies rely on interviews with small samples of firms, however, making their evidence merely suggestive.[35]

3.2 Micro-level evidence: the social impacts of GVC production

3.2.1 Finding 8: GVCs are associated with income premia

An important finding is that economic agents which participate in GVCs tend to receive an income premium because of their value chain engagement, when compared to their counterparts operating mainly on domestic markets. Income premia benefit workers and producers alike. For manufacturing firms, for instance, wage differentials between GVC participants and domestic firms are well documented. I find evidence of wage premia for workers employed by foreign firms and MNEs (Lipsey and Sjoholm, 2003; Girma and Görg, 2007; OECD, 2008), exporters (Schank et al., 2007; Kandilov, 2009), as well as for workers in industrial parks and export processing zones (EPZs) (Cirera and Lakshman, 2017).

Income premia are documented in agriculture too, particularly for smallholder farmers acting as suppliers to exporters and processors in the context of GVCs (Swinnen and Kuijpers, 2020). Oya et al. (2018) review 10 empirical studies which compare certified and non-certified agricultural producers. To an extent, this comparison is equivalent to that between exporters and non-exporters in manufacturing. While many agricultural crops are almost entirely for export, certified farmers tend to be more clearly associated to GVCs. Certification is an increasingly important requirement to sell one's produce within value chains coordinated by food MNEs, particularly in the context of high value agricultural commodities, such as coffee or cocoa, and fresh fruit and vegetable production. Certified farmers often enjoy benefits such as price premia and training opportunities.

Oya et al. (2018) find that certification has positive and statistically significant effects on farmers' income. They report an average difference of 22 percent between certified and non-certified smallholders across the studies they review.[36] Similarly, in her review of empirical

[34] ISO 14001 defines the criteria for environmental management systems (EMS).
[35] Aron and Molina (2020) interview five firms, De Marchi et al. (2013) four, and Khattak (2015) three. The UNCTAD (2010) report relies on interviews with six first-tier and two second-tier suppliers.
[36] To facilitate comparisons across a range of different studies, Oya et al. (2018) calculate effect size estimates for the outcomes in the studies they review using standardised mean differences. These are calculated as the difference

work which also compares certified and non-certified farmers, Meemken (2020) reports that certification is associated with higher revenues—she finds a median percentage difference of over 32 percent between the two groups.[37]

Both studies also offer some clues as to the mechanisms linking certification to income effects. There is mixed evidence on the effects of certification on farm yield, but positive and statistically significant effects on certification and the prices of agricultural produce (Oya et al., 2018; Meemken, 2020). These findings suggest that the relationship between farmers' income and certification is driven primarily by the higher prices commanded by certified products, rather than by scale or productivity effects which are more commonly observed in manufacturing.[38] Macchiavello and Miquel-Florensa (2019) corroborate these findings. They study the introduction of a voluntary sustainability standard in the Colombian coffee value chain and find that certification leads to a 17 percent increase in farmers' profits, largely due to price premia.

Certification appears to have a positive effect on measures of welfare at the household level too, although the magnitude of reported effects tends to be smaller and not always statistically different from zero. Meemken (2020) reports a positive impact of certification on household-level income and consumption. She finds a 16 percent median difference between households linked to a certified farm and other households. Similarly, Sellare et al. (2020) find that Fairtrade certification is associated with a 15 percent increase in consumption expenditure in the Ivorian cocoa value chain, controlling for the characteristics of households and cooperatives of which farmers are members.[39] By contrast, Oya et al. (2018) find no statistically discernible impact of certification on household-level income.[40]

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between the mean of the treatment versus the control group, divided by the pooled standard deviation of the population from which the groups were sampled.

[37] In contrast with Oya et al. (2018), Meemken (2020) does not account for variance in calculating effect sizes across a range of different studies. Rather, she simply calculates percentage differences between treatment and control groups, and weights these by the sample size reported in the corresponding study. While the lack of standardisation makes her estimates less accurate, it enables her to cover a somewhat larger literature.

[38] That productivity should not be the main driver of income effects in agriculture is likely because not all certification schemes target productivity increases as an objective. In some instances, certification is accompanied by training and extension services aimed at improving productivity. Yet in other cases, certification is aimed at preserving organic practices, which are associated with lower average yields (Oya et al., 2018).

[39] Relative to other studies in this literature, Sellare et al. (2020) pay greater attention to questions of endogeneity in the relationship between the choice of becoming certified and their outcome variables. Similarly to Suzuki (2018) they include individual-level psychological indicators, such as risk-aversion and trust, to account for unobservable characteristics which might drive both certification and outcomes. They also instrument the Fairtrade certification choice by using indicators of farmers' exposure to social networks, which are likely to impact the choice of acquiring a certification but unlikely to influence outcome variables such as coca yields or living standards.

[40] It is worth noting that since Meemken (2020) aims for a more comprehensive review of the literature relative to Oya et al. (2018), she explicitly chooses not to exclude literature based on quality grounds. Whereas the total number of empirical studies covered in the Meemken (2020) review is 97, Oya et al. (2018) only select 43. The estimates she calculates are therefore likely to have some bias. Both meta-analyses estimate and report pooled effects across different studies to standardize results and make it possible to quantify differences in effect size across the literature.

I also find, however, that standardisation in GVCs can exclude farmers in some instances (see, for instance, Maertens and Swinnen, 2009; and Schuster and Maertens, 2013, on the Senegalese and Peruvian horticultural sectors, respectively).[41] Certification is often a pre-requisite for farmers to sell their produce to exporters or buyers in high-income markets, and not all producers can shoulder the costs and requirements associated with certification. To reconcile these findings, Swinnen and Kuijpers (2020) suggest that smallholder inclusion depends on the presence of large farms, which reduces incentives to source from smaller producers, and on the relative power of producers, buyers, and middlemen within a chain. Lee et al. (2012) echo this point. Looking at the degree of concentration in production and retail, they argue that farmers tend to profit more by engaging in buyer-driven chains—common, for instance, in horticulture. By contrast in the producer-driven chains characterising coffee and cocoa production, processors are central and are thus able to capture larger profits—often at the expense of farmers.[42]

When smallholders cannot keep up with the demands of standardisations, labour market participation becomes an alternative income-generating channel for workers and households. Micro-econometric literature on the welfare effects of this channel is relatively more recent. Van den Broeck et al. (2017) study the effects of wage employment in Senegal's horticultural export sector on household income. Using panel data for 255 households deriving from two waves of a survey, they find that wage employment increases household income—by 53 and 49 percent, respectively, for households in the two bottom quantiles of the income distribution. They also find, however, that employment in any other sector has similar effects on household income, although these effects tend to be less pronounced for poorer households relative to agricultural employment.

Suzuki et al. (2018) use PSM to study the welfare effects of wage employment within Ethiopia's cut-flower export industry. Thanks to substantial FDI inflows and government support, the industry has expanded considerably in recent years, and is often considered a success story of GVC-oriented agricultural development. Suzuki et al. (2018) find that wage employment raises household incomes by 26 percent on average. They rely on a cross-section, however, and their selection of treatment and control groups is somewhat problematic.[43] The potential welfare effects of wage employment extend beyond income. Literature using

[41] There is no a priori reason to think that the more stringent product and production standards associated with agricultural GVCs should either damage or benefit smallholder producers. While buyers might prefer sourcing from larger farms or opt for vertical integration to reduce transaction costs, small producers may have a cost advantage—particularly in labour-intensive production with small economies of scale (Swinnen and Kuijpers, 2020).

[42] Standardization within buyer-driven chains such as the cut flower value chain is linked to social benefits by Riisegard and Hammer (2011) too, who find that the widespread adoption of standards has brought about unionization and greater awareness of ILO regulations.

[43] While treated workers are selected at random, the control group is constructed by asking members of the treatment group to identify, among their acquaintances, individuals with similar characteristics. PSM is then used to establish a clearer counterfactual. Questions on psychological traits and competences are used to make unobservable characteristics observable, thus helping with the matching.

qualitative and mixed methods links wage employment to the opportunity for empowerment, particularly for groups who are likely to be marginalised, as unpaid or underpaid family labour, in the context of smallholder agriculture (Said-Allsopp and Tallontire, 2015; Barrientos, 2019).

Despite these findings, I find limited evidence that wages in firms embedded within GVCs are *higher* relative to the prevailing wage rate. Colen et al. (2012) find that employees of certified farmers in the Senegalese fresh fruit sector do receive higher wages using cross-section and panel regressions. When reviewing the empirical evidence on wages, however, Oya et al. (2018) find that certified farms do not pay higher wages relative to non-certified farms. Similarly, Schuster and Maertens (2016) find that exporters within the Peruvian horticultural industry are more likely to pay minimum wage—but they find no evidence on the level of wages. Meemken et al. (2019) study wage levels among Ivorian cocoa farmers with and without a Fairtrade certification, and find no discernible difference between the two groups. At the other extreme is Cramer et al. (2014)'s study of coffee, tea, and flower growers in Ethiopia and Uganda, which finds that Fairtrade-certified farmers pay lower wages relative to non-certified farmers.

I also find evidence of welfare-enhancing effects of wage employment within mining GVCs, although there is no consensus in this area. In a study of 29 Sub-Saharan African countries which combines geocoded information on households from the Demographic and Health Surveys (DHS) and data on the location of industrial mines in multiple countries, Kotsadam and Benshaul-Tolonen (2016) find that the opening of a new mine is associated with a shift into paid employment for women. Similarly, in their study of gold mining in Ghana Benshaul-Tolonen et al. (2019) find that in those households living less than 20 km away from an active mine, both men and women are more likely to be in wage employment relative to households living further away, with men being employed directly in mining operations and women being employed in the services activities that emerge around industrial mines.

That participation in mining activities might be something of a mixed blessing for households is the conclusion of Van der Gotz and Barnwal (2019). They focus on 44 developing economies and report that households living close to an area which was ever exposed to mining operations are wealthier—an effect of 0.26 standard deviation in their panel model, which they consider comparable to owning a motorbike or a mobile phone in a Sub-Saharan African country—but also experience a higher incidence of health effects related to exposure to toxic metals, including anaemia and child stunting. Buse et al. (2019) also find that most studies in their review do report positive effects, on average, on the income and employment opportunities of communities living near UNG extraction sites, alongside negative repercussions for health.

Yet there is also evidence of null and negative effects on income and consumption related to mining GVCs. Pokorny et al. (2019) survey 600 households in six different provinces in Burkina Faso—two of which host industrial mining operations. They find that large-scale mining does not seem to be associated with income generation at the household level. Bazillier and Girard (2020) also study the case of Burkina Faso and corroborate these findings using a nationally representative survey of 30,000 households. Taking advantage of geocoded information on households' dwellings, they find no discernible effect on household consumption for those households living within a 10 km radius of an industrial mine relative to households living further away. In a cross-country-setting, Wegenast and Beck (2020) find that industrial mines are negatively associated with access to food, particularly among female members of the household across Sub-Saharan Africa.

3.2.2 Finding 9: Labour conditions in GVCs are heterogenous: lower-tier firms and irregular workers fare worse

Micro-econometric literature on labour conditions within GVCs is scarcer. A recent exception is Boudreau (2020), who studies an initiative by multinational buyers to increase factory safety within the Bangladeshi apparel industry by establishing worker-management safety councils. Out of 84 garment factories, 41 are randomly assigned to participate to the initiative. Her findings indicate that the establishment of safety council improves factories' adherence to labour laws and regulations and have positive impacts on worker's health. Boudreau (2020) also highlights the moderating role of management, with the results being driven by improvements in firms with better management practices.[44] This last finding resonates with Distelhorst et al. (2016) who link the adoption of lean manufacturing to increased adherence to labour standards for a sample of 300 Nike suppliers.

While these two pieces of evidence shed light on the possible beneficial impacts of MNE enforcement of labour standards in developing and emerging economies, more research and evidence from other countries and industries would be required to draw firmer conclusions. The most recent available review into labour standards and health and safety impacts for workers in industrial parks and EPZs, for instance, tends to find a markedly more mixed picture. In EPZs, unionisation tends to be discouraged, and health and safety issues, particularly among female workers, are documented (Cirera and Lakshman, 2017). It is difficult, however, to assess whether these issues are more prevalent within EPZs relative to the rest of the economy.

An important aspect which is missing from work such as Boudreau (2020) and Distelhorst et al. (2016) is whether social impacts from international trade and production are different for different types of workers and establishments. Heterogeneity among regular and irregular workers, but also among suppliers in different tiers of the value chain is the main finding of a relatively extensive literature of case studies that has investigated the social implications of GVC participation.

In her qualitative work on Moroccan garment factories supplying European fashion brands, for instance, Rossi (2013) finds that supplying within GVCs seems to benefit regular workers with

[44] There is also evidence that management practices have a positive impact on the environmental performance of firms (Bloom et al., 2010).

stable contracts. In interviews with workers of 19 garment plants, she finds evidence that labour conditions for this category of workers improve when plants start supplying MNCs. Workers also report receiving training and skill upgrading opportunities. Irregular workers, by contrast, whose presence tends to expand because of buyers' requirements for just-in-time delivery, report experiencing hardly any improvement (Rossi, 2013, see also 2011).

The presence of a dual workforce within suppliers to MNEs in GVCs—and the chasm in labour conditions between the two groups—is a common finding in this literature. Dual workforces are documented in manufacturing. Pasquali (2020) reports the co-existence of regular and irregular workers in Kenya's export-oriented leather goods suppliers, and so do Mezzadri (2014) among Indian garment suppliers, and Lund-Thomsen et al. (2012) among football producers in China, India, and Pakistan. These studies also find marked differences between first- and lower-tier suppliers. In a qualitative study on workers and other stakeholders in one of India's largest garment clusters in Uttar Pradesh, Mezzadri (2014) finds that exporters in clusters represent the top layer of a complex web of second- and third-tier suppliers, as well as home-based producers. Descent into the bottom layers tends to be associated, she finds, with increasingly informal and precarious employment conditions (Mezzadri, 2014).

In their case study of football factories, stitching centres, and home-based work over the 2008-2010 period, Lund-Thomsen et al. (2012) reach similar conclusions. Subcontracting is the norm, which means that many workers in the football production value chain are not fully employed by exporters or first-tier suppliers, but rather in the lower layers in the chain, where informal agreements and piece-rate work prevail. The vast majority of workers employed at home or in stitching centres, as opposed to factories, also report experiencing occupational-related health and safety issues (Lund-Thomsen et al., 2012).

Similar evidence emerges from studies of agriculture. Barrientos (2019) reviews evidence on the fruit export sector in South Africa. While she confirms that large growers do provide stable employment, she also reports that the need to ensure timely and flexible deliveries has increased growers' reliance on seasonal and casual labour—a category wherein women tend to be overrepresented. Relying on interviews with regular and occasional workers in the Tanzanian horticultural industry, De Blasis (2020) reports similar findings. Casual labourers experience poorer working conditions and earn less—the yearly income of an informal labourer is estimated at around 280 US dollars, against upwards of 620 US dollars for regular workers (De Blasis, 2020).[45] When coupled with regulatory voids, the use of precarious labour arrangements can reach particularly abusive conditions in the case of migrant workers, as reported, for instance by Stringer et al. (2016) in New Zealand's fishing industry.

[45] These figures are simple conversions, not adjusted in line with PPP.

While sample sizes and selection for all these studies mean that none can claim to be representative, taken together they do provide some indication that the social impacts of GVC production are likely to be heterogeneous across different types of workers and firms.

3.3 Discussion

On average, both exporters and importers display a better environmental performance relative to non-traders. Mechanisms differ markedly for the two groups, however. Particularly in high-income economies, the evidence suggests that importing is associated to lower emissions because importers have offshored the production of relatively more polluting inputs. While I find no evidence that offshoring occurs in response to changes in the stringency of environmental regulation, this is still an important finding which resonates with the evidence on carbon leakage discussed in Section 2.1. At the same time, at least one study suggests that importing might also have environmental benefits insofar as it makes firms more productive and, therefore, more resource efficient (Imbruno and Ketterer, 2018).

Even in the case of exporters, however, assessing environmental impacts is not always straightforward. Counterfactuals are important here. Exporters have lower emission intensities, but only relative to firms which do not trade in the same country. Insofar as it allows firms to scale up production, exporting is not necessarily carbon neutral—particularly if exporters are in countries with relatively dirty energy systems. A related observation concerns substitutability. Consider the case of foreign acquisitions. While newly acquired firms may be more resource efficient than their locally owned counterparts, their environmental impact may, in fact, depend on how clean the prevailing energy system is, as well as on whether any goods they produce and export substitute for goods previously produced using relatively cleaner electricity.[46] In general then, the evidence points to relatively narrow environmental gains.

These findings come from studies of manufacturing firms. Quasi-experimental evidence linking certification, exporting, or FDI in agriculture to environmental impacts is harder to find, at least in economics. I find some evidence of environmental externalities, such as deforestation, resulting from smallholder production. Particularly with regard to certain commodities such as palm oil, this finding relates to the discussions on the role of consumption in driving environmental impacts which feature prominently in the MRIO literature. Yet we know little on the environmental sustainability of larger-scale farming for export, particularly in sectors—such as high-value horticulture and floriculture and other non-traditional agricultural exports—which have received significant attention in recent years due to their rapid integration within GVCs.

One of the drawbacks involved in choosing to collect evidence on different sectors is that the indicators to measure the environmental impacts of firms, farms, and mines differ substantially.

[46] Questions of substitutability are arguably less relevant in the context of agriculture or extractive activities. While one could produce and export intermediate goods from almost any location, provided a certain level of production capabilities is present, agricultural commodities are more dependent on climate and soil conditions.

All these agents tend to scale up following entry in export markets. Yet while manufacturing firms appear to become more efficient in their use of resources and energy, the literature I review does not study the environmental efficiency of agricultural producers or industrial mines. This is not necessarily surprising. Economies of scale are likely to be more limited in agriculture than in manufacturing.[47] At the same time, just as efficiency dominates the discussion in manufacturing but is largely absent from the literature on agriculture and mining, the opposite is true of environmental externalities.

I also find that employment within GVCs is associated with welfare gains—in terms of income, consumption, and working conditions—although these benefits do not extend to all. Case studies suggest that the evidence is much more mixed for irregular workers and for informal firms. Heterogenous effects across different categories of workers and firms remain under-explored in quantitatively oriented literature. Evidence of wage levels is mixed. I find evidence of wage premia in manufacturing, but not in other sectors. An important policy issue which cuts across multiple strands of literature concerns the trade-offs between expanding socio-economic opportunities in agriculture and mining, and the environmental externalities deriving from changes in land use patterns and poor environmental management.

4. Summary

This paper has reviewed macro- and micro-level evidence on the environmental and social sustainability of production in GVCs. The evidence I collect suggests that GVCs have contributed to increasing emissions worldwide due to "weak" carbon leakage, whereby firms offshore relatively more polluting inputs to countries where production is more carbon intensive. While the magnitude of carbon leakage remains a subject for discussion, there is consensus that it should not be considered the primary driver of emission growth. Rather, global emissions are driven by rising consumption levels—primarily in higher-income economies, but increasingly in emerging economies such as China.

There is also evidence that production by manufacturing traders is less emission- and energy-intensive than production by firms that do not trade, and that exporting has a causal effect on environmental performance at the firm-level. Foreign investment has also been linked to improvements in environmental performance, possibly as a result of knowledge transfer from MNEs to local firms. Taken together, these results suggest that—at least insofar as manufacturing firms are concerned—GVC participation may have a more neutral effect on the environment than that suggested by MRIO models. As I argue in the next section, more evidence on the diffusion of green technologies and products within GVCs would help shed light on the environmental impacts of GVC trade and production.

[47] In their study of the impacts of certification, Giuliani et al. (2017) find a positive relationship between farm size and their performance on a number of environmental management indicators, but more evidence would be required to draw any conclusion here.

In general, then, GVCs are found to contribute to global emission growth through scale and specialisation effects—two themes that appear frequently in both micro- and macro-level literature. At the same time, GVCs are associated with an environmental and energy efficiency premium, suggesting that the very expansion of GVCs simultaneously contributes to dampening emission growth. The relative magnitude of these countervailing effects remains unclear, as the literature reviewed in this paper typically considers these aspects in isolation. Work using structural decomposition methods does suggest, however, that technical change does not fully offset the worldwide growth in emission (Hoekstra et al., 2016; de Vries and Ferrarini, 2017).

With regard to the social impacts of GVC production, the evidence is mixed. There is ample evidence that workers and households benefit from participation and employment within GVCs in one form or another. Mechanisms differ across sectors—manufacturing GVCs are linked to wage premia, whereas agricultural and extractive GVCs are found to be associated with positive impacts on income and consumption at the household level—but findings are similar. At the same time, several case studies find adverse social impacts, particularly among irregular workers, informal firms, and lower-tier suppliers to exporters and MNEs. More evidence on these "local" aspects of GVCs, particularly in developing economies, would be critical in providing a more complete picture of the social sustainability of GVC production.

5. Research gaps and directions for future research

I now turn to discussing a number of areas which remain unexplored in the literature. Some of these research gaps are due to limitations in the availability and reliability of data, requiring efforts in collecting and collating new data. Others could be addressed with data that is currently available. In what follows, I list these gaps and reflect on how one might begin addressing them.

First is the extent to which green technologies diffuse along GVCs. Case studies highlight that, in some instances, suppliers to MNEs adopt cleaner technologies and environmental standards.[48] I also find evidence that FDI can act as a channel for the diffusion of new technology and management practices, with positive consequences for environmental performance. Yet evidence on green technology diffusion in GVCs remains largely anecdotal. To shed light on this issue, researchers could leverage several sources of macro- and micro-level data. The use of MRIO tables together with industry-level data on patent citations could help estimating technology spillovers between different industries and countries in the spirit of work on technology flow matrices (see, for instance, Mohnen, 1997; Verspagen, 1997), but with a specific focus on green technologies.

[48] In its latest *World Development Report*, the World Bank (2020) provides examples of MNE-led sustainability initiatives within clothing supply chains.

On the micro side, one could assess whether importers—particularly in developing economies—are able to gain access to cleaner intermediate and capital goods on international markets, relative to those which are available domestically. Data requirements are somewhat more taxing for this exercise, as this would require access to product-level information on firm- or plant-level imports. Data on imports would then have be matched to existing classifications on the environmental sustainability of different products. Should product-level data on imports not be accessible, input-output data on the industry-level emissions of a country or industry's trading partners—as available, for instance, in WIOD—could be used to gauge the average environmental impact of imports (this is part of the approach of Dussaux et al., 2020).

A second and interrelated research gap concerns the product composition of international demand. Understanding whether countries trade in relatively greener goods would go a long way in helping one to assess the sustainability of GVCs. MRIO models, however, do not feature product-level information, and micro-level studies tend to be focused on single economies rather than on cross-country trade patterns. Two studies have recently put forward product-level classification focused on environmental characteristics. Mealy and Teytelboym (2020) seek to harmonize existing classifications and link them to measures of economic complexity. Romero and Gramkow (2021) also build on the product space literature to derive a product-level emission intensity index for 786 products at the 4-digit level. Future work could build upon these data collection and harmonization efforts to study cross-country trade patterns in specific sub-sets of products.[49]

A third gap concerns evidence on wage levels and labour conditions for workers in lower-tier suppliers to exporters and MNEs within GVCs. Qualitative literature suggests lower wages and unsustainable labour practices tend to be relatively common in these firms, particularly when they belong to the informal economy and rely on irregular employees. So far, however, econometric studies have not investigated these actors, largely due to lack of data. This is an area where administrative data collection is unlikely to make any significant inroads for the time being. Carefully designed surveys tailored around specific sections of value chains, however, might be able to bring forward new data on which to build rigorous evidence on an important topic.

Primary data collection would also be required to shed light on another topic on which there is contradictory and inconclusive evidence—wage levels in large-scale export agriculture. This is the fourth and final research gap I highlight. Literature on the labour market effects of increased GVC participation in agriculture is relatively recent. We know, from literature focused on manufacturing firms, that GVC participation is associated with a wage premium—

[49] One limitation with these classifications is that they assume a correspondence between countries' and products' emission intensities. The use of emission and product-level data for manufacturing plants in individual countries could help overcome this difficulty and paint a more realistic picture of a countries' trade-embodied environmental impacts.

for the average worker, at least. Evidence from export-oriented farms is scarce and largely inconclusive. Researchers could design multi-year surveys targeting specific agricultural commodities—such as horticulture in East Africa, which has received significant attention in recent years—and compare the wage levels of export-oriented farms with those of other local farms, or relative to the prevailing wage rate in the sector or region.

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