Ingrid Schistad Berg

Green jobs

Drivers of emissions and employment in emerging economies

Master's thesis in Industrial Ecology
Supervisor: Richard Wood and Moana Simas
June 2019

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Energy and Process Engineering

NTNU
Norwegian University of
Science and Technology

Ingrid Schistad Berg

Green jobs

Drivers of emissions and employment in emerging economies

Master's thesis in Industrial Ecology
Supervisor: Richard Wood and Moana Simas
June 2019

Norwegian University of Science and Technology
Faculty of Engineering
Department of Energy and Process Engineering

NTNU
Norwegian University of
Science and Technology

Abstract

The BRIICS countries - Brazil, Russia, India, Indonesia, China and South Africa – have the past few decades experienced fast economic growth, especially due to their growing participation in international trade. This has contributed to job creation and allowed the populations to increase their consumption and standards of living but has also increased the BRIICS' greenhouse gas (GHG) emissions from production, and their carbon footprints. To reduce carbon emissions while contributing to continued economic growth, the concept of "green jobs" has been promoted. There are many ways of defining and quantifying green jobs, and in this thesis GHG emissions per job was used as an indicator. GHG emission intensities of jobs in both production and consumption of the BRIICS are catching up with the intensities of jobs in developed countries, even though consumption and development levels are not yet catching up, implying that future jobs created in the BRIICS will cause a higher environmental pressure than jobs in developed countries.

Multi-regional input-output analysis and structural decomposition analysis was used in this thesis to determine what factors have been most influential in generating emissions and jobs in the BRIICS' consumption and exports between 1995 and 2011, as this can contribute to knowledge about what factors to target to avoid further growth in emission intensities of jobs. This approach allows quantifying the impacts in the supply chains of the BRIICS' consumption, a group of countries that have previously mainly been studied from a producer perspective but are now becoming important global consumers. Further, it allows studying the role of international trade specifically, which is becoming more important for the BRIICS, and studying determinants of jobs and emissions in one consistent framework.

The amount of jobs in the BRIICS has been relatively stable over the time period, while emissions have been growing fast, which explains the growing emission intensities of jobs. The emission intensities of jobs are especially high in sectors like electricity, mining and metals, while they are low in services and to some extent in agriculture. The main driver of emissions and jobs in both consumption and exports has been growth in demand, and their exports shifted towards more carbon-intensive products in most of the BRIICS. The BRIICS started consuming more sophisticated manufactured goods and services at the expense of agricultural products, and the share of footprints imported is growing fast. These changes are likely to become important as the countries continue developing and adopting the lifestyles of more developed countries. Technologies in supply chains and in the BRIICS' exports improved significantly, contributing to slowing the emission growth and making labour more productive. However, especially in the case of emissions, technologies have not been improving fast enough to offset the growing consumption.

Consumption will continue growing in the BRIICS, meaning that it must be decoupled from emission growth through changes in consumption patterns or technology. More sustainable consumption patterns should hence be encouraged, for example by changes in diets, transport modes or energy sources, as well as buying their imported goods from the most efficient production locations. For generation of green jobs, replacing consumption of goods with services is of particularly high importance because of the low amounts of emissions generated for each job created in services. Further, the large gap between carbon intensities of production in emerging and developed countries suggest that there is a great potential for improvements and for technology transfers.

Sammendrag

BRIICS-landene – Brasil, Russland, India, Indonesia, Kina og Sør-Afrika – har de siste tiårene opplevd rask økonomisk vekst, spesielt på grunn av deres økende deltakelse i internasjonal handel. Dette har bidratt til arbeidsplasskapning, og at befolkningene har kunnet øke sitt forbruk og levestandard, men har også ført til økte klimafotavtrykk og økte utslipp av drivhusgasser i BRIICS' produksjon. For å redusere klimautslipp og samtidig bidra til fortsatt økonomisk vekst har konseptet «grønne jobber» blitt fremmet. Det finnes mange måter å definere og kvantifisere grønne jobber, og i denne oppgaven har klimautslipp per jobb blitt brukt som en indikator. I både produksjon og forbruk har klimautslipp per arbeidsplass i BRIICS begynt å ta igjen nivåene i utviklede land, selv om nivået på forbruk og utvikling i disse landene fortsatt ikke tar igjen nivåene i utviklede land. Dette tilsier at i fremtiden vil hver arbeidsplass skapt i BRIICS' produksjon eller forbruk forårsake større skade på miljøet enn arbeidsplasser i utviklede land.

Multi-regional kryssløpsanalyse og «structural decomposition»-analyse ble brukt i denne oppgaven for å undersøke hvilke faktorer som har hatt størst påvirkning på vekst i klimautslipp og jobbskapning i BRIICS-landenes forbruk og eksport mellom 1995 og 2011. Dette kan bidra til kunnskap om hvilke faktorer som bør fokuseres på for å unngå videre vekst i klimautslipp per arbeidsplass. Fordelen med denne metoden er at den gjør det mulig å kvantifisere effekter i forsyningskjedene til BRIICS' forbruk, en gruppe som tidligere først og fremst har blitt studert fra et produksjonsperspektiv, men som nå er i ferd med å bli viktige globale forbrukere. I tillegg er det mulig å eksplisitt studere hvilken rolle internasjonal handel har i å skape effekter, noe som blir viktigere fremover for BRIICS, og metoden gjør det mulig å studere jobber og utslipp innenfor ett konsistent rammeverk.

Antall jobber i BRIICS har vært relativt stabilt gjennom perioden, mens klimautslipp har vokst raskt, noe som forklarer de voksende utslippsintensitetene til jobber. Klimautslipp per jobb er spesielt høye i sektorer som elektrisitet, gruvedrift og metaller, mens de er lave i tjenester og til en viss grad i jordbruk. Den viktigste driveren av utslipp og jobber i både forbruk og eksport har vært vekst i etterspørsel, og spesielt eksportetterspørselen har skiftet i retning av mer forurensende produkter fra de fleste av BRIICS-landene. BRIICS har begynt å konsumere en større andel avanserte produkter og tjenester på bekostning av jordbruksprodukter, og andelen av fotavtrykkene forårsaket av import øker raskt. Disse endringene var relativt mindre viktige for endringene i fotavtrykkene sammenlignet med andre faktorer, men vil sannsynligvis bli viktigere når landene fortsetter sin utvikling og får livsstiler mer like dem i utviklede land. Teknologier i forsyningskjedene og i BRIICS' eksport forbedret seg vesentlig, og bidro til å redusere veksten i utslipp og til mer produktiv arbeidskraft, men spesielt i forhold til utslipp har ikke teknologiendringer skjedd raskt nok til å utligne effekten av voksende forbruk.

Forbruket vil fortsette å vokse i BRIICS, og derfor må forbruket frikobles fra vekst i utslipp gjennom endringer i forbruksmønster eller teknologier. Altså bør man oppfordre til mer bærekraftige forbruksmønster, som for eksempel endringer i dietter, transportvaner eller energikilder, og importerte goder bør komme fra de mest produktive stedene. For å skape grønne jobber er det spesielt viktig å bytte ut forbruk av fysiske varer med kjøp av tjenester, da tjenester skaper spesielt lave utslipp per arbeidsplass. De store forskjellene mellom utslippsintensiteter i produksjonen i fremvoksende land og utviklede land tilsier at det fins stort potensiale for forbedringer og for overføring av teknologi.

Preface

This thesis completes my master's degree in Industrial Ecology at NTNU. The master thesis is a continuation of a project thesis done in the fall semester 2018. In the project, I calculated the changes in environmental intensities of jobs in the BRIICS countries between 1995 and 2011 and compared these with those of developed countries. This thesis is a continuation of the project, in the sense that I am now analysing what underlying factors contributed to these changes in GHG emissions and employment in the BRIICS.

Thank you to my supervisors Richard Wood and Moana Simas for help in defining the project and for very useful inputs and discussion during the work. Especially thanks to Moana for a lot of patience in discussing the details with me and reading the drafts of my thesis.

Table of contents

Figures

Tables

Abbreviations

BRICS	–	Brazil, Russia, India, China, South Africa
BRIIC	–	Brazil, Russia, India, Indonesia, China
BRIICS	–	Brazil, Russia, India, Indonesia, China, South Africa
EEBT	–	emissions embodied in bilateral trade
GDP	–	gross domestic product
GHG	–	greenhouse gas
HDI	–	human development index
IDA	–	index decomposition analysis
IEA	–	International Energy Agency
ILO	–	International Labour Organization
IO	–	input-output
IPAT	–	impact = population x affluence x technology
LCA	–	life cycle assessment
LMDI	–	logarithmic mean divisia index
MRIO	–	multi-regional input-output
OECD	–	Organization for Economic Co-operation and Development
ROW	–	rest of the world
SDA	–	structural decomposition analysis
STIRPAT	-	stochastic impact regression on population, affluence and technology
UNEP	–	United Nations Environment Programme
VA	–	value added
WTO	–	World Trade Organization

1. Introduction

1.1. Growing emission intensities of jobs

Developed countries have lately managed to stabilize or reduce their greenhouse gas (GHG) emissions from production, but emissions have still been growing fast in developing countries, and significant shares of the global emissions are now occurring in emerging countries like the BRIICS – Brazil, Russia, India, Indonesia, China and South Africa (Hoekstra, Michel, & Suh, 2016; Le Quéré et al., 2009; Peters, Minx, Weber, & Edenhofer, 2011; Raupach et al., 2007; Y. Xu & Dietzenbacher, 2014). Emissions in international trade have been growing faster than global emissions, so the stabilizing of emissions in developed countries and growth in developing countries can at least partly be explained by outsourcing of production from developed to developing countries (Arto & Dietzenbacher, 2014; Le Quéré et al., 2009; Peters et al., 2011). The emerging countries are also experiencing high economic growth due to their growing participation in international trade, and becoming important global consumers and drivers of emissions as well (Arto, Rueda-Cantuche, Andreoni, Mongelli, & Genty, 2014; Meng et al., 2018; Singh & Dube, 2014). GHG emissions need to be reduced to avoid irreversible climate change, and the reductions should preferably happen in a way that is compatible with sustainable development, allowing developing countries to continue gaining economic and social benefits (Rockström et al., 2009; Steffen et al., 2015; United Nations, 2015b).

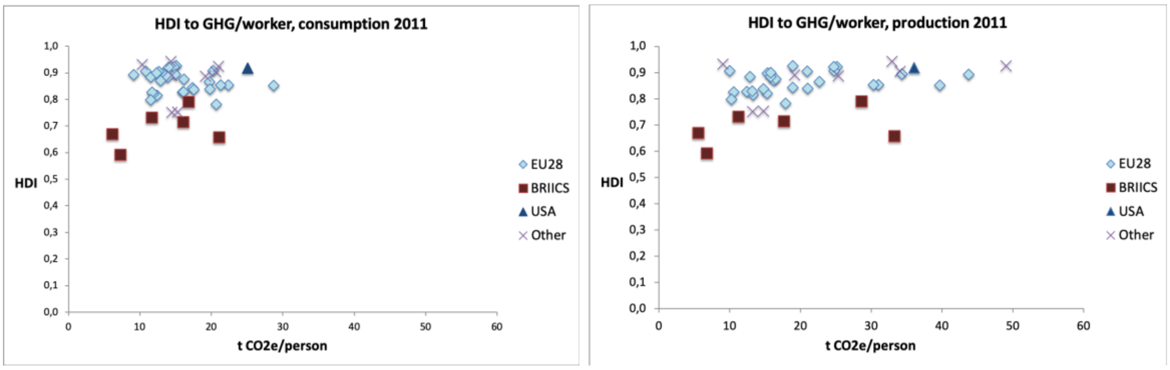


Figure 1 - GHG intensities of jobs in countries with different human development index (HDI) levels, from Berg (2018).

While generating GHG emissions, the production in the emerging countries is also contributing to important benefits like economic growth and employment. The ratio of emissions to jobs in production are higher in developed than developing countries, because as countries grow richer, they tend to use more energy relative to labour in production (International Labour Organization, 2018; Simas, Wood, & Hertwich, 2015). However, the GHG emission intensities of jobs in the BRIICS countries are increasing and are starting to catch up with the intensities of jobs in developed countries in both production and consumption (Figure 1; Berg, 2018). Still, the developed countries consistently have a higher human development index (HDI)[1] than the BRIICS countries. This implies that when emerging countries reach similar human development levels as developed countries, they may emit a significantly higher amount of greenhouse gases and other pollutants for each job that is created.

[1] HDI is the UN's human development index and describes how well a country is performing in terms of health, education and income (UNDP, 2018).

"Green jobs" is a concept that is promoted to achieve emission reductions along with continued economic development. Green jobs are defined by the International Labour Organization (ILO) and the United Nations Environment Programme (UNEP) as *"jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution"* (Renner, Sweeney, & Kubit, 2008, p. 3), and green jobs should also be decent in terms of wages, working conditions and worker's rights. However, several other definitions of green jobs exist as well, for example based on being part of certain industries, producing certain goods or requiring certain skill sets that are defined as green (Cox & Foley, 2013; OECD, 2012). This variety of definitions means that there are many approaches to quantifying green jobs. GHG intensities of jobs is one of these options, and is useful as it allows for comparing the "greenness" of jobs for example across sectors, regions or supply chains, and provides insight into what sectors or regions are more or less sensitive to job losses as a consequence of climate mitigation (Arto et al., 2014; Tang, McLellan, Zhang, Snowden, & Höök, 2016; Templet, 1993). The growing emission intensities of jobs in the BRIICS suggest that jobs are currently becoming less green, and this trend needs to be reversed in order to generate green jobs.

The BRICS countries are studied in this project because they are emerging countries that have become important in the global economy and international trade, and they are important employers due to their large share of global population (Singh & Dube, 2014). From 1990 to 2014, the share of the BRICS in global gross domestic product (GDP) increased from 10 to 25%. In 2016 almost 19% of the value of exported goods came from the BRICS, and manufactured goods are especially important (UNCTAD, 2018). These countries are also home to two fifths of the world population and a slightly higher share of the global labour force (Singh & Dube, 2014). Indonesia is also included in this analysis, hence the acronym BRIICS, because of its important size as the world's 16th largest economy and the fourth largest population, and its fast growth which means that it will become very important in the future (World Bank, 2018, 2019d). Altogether this means that this group of countries have an important role and growing influence in the world economy (Nayyar, 2016; Singh & Dube, 2014).

Arto and Dietzenbacher (2014) found that 44% of the growth in global GHG emissions from 1995 to 2008 was caused by changes occurring in the BRIIC countries. Large shares of the growth in these countries' emissions can be attributed to exports to more advanced countries, and especially China has an important role in this. However, according to Pan et al. (2017) the emissions in exports from developing countries to developed are now stabilizing because of large improvements in China's technologies and economic structure. Still, China, India, Indonesia and Russia are all among the top ten exporters of emissions globally and China and India are also among the top ten importers of emissions (Y. Xu & Dietzenbacher, 2014). In the future, the growing consumption in emerging economies is expected to become the main driver of growth in global emissions. Still, they also have a large potential to make improvements in technology that can significantly reduce global emissions (Arto & Dietzenbacher, 2014).

To be able to reduce emissions while generating jobs in the emerging economies, it is key to know what factors have been driving the changes in these impacts over time (Kopidou, Tsakanikas, & Diakoulaki, 2016). Two common approaches used for analysing drivers of emissions, and to a lesser extent employment, are index decomposition analysis (IDA) and structural decomposition analysis (SDA). These approaches study the isolated effect of drivers on impacts. The most important drivers of environmental impacts are identified by the IPAT relation, defining the environmental impact (I) as the product of population (P), affluence (A) and technology (T) (Rosa & Dietz, 2012). In addition, footprints may be influenced by changes in international trade, because of differences in production across countries. Most studies find that increasing consumption per capita and population growth have been the main drivers of emissions, while carbon emissions per unit of production has improved in most countries and offset the growth in emissions slightly (Arto & Dietzenbacher, 2014; de Vries & Ferrarini, 2017; Hoekstra et al., 2016; Malik & Lan, 2016). The few papers that study drivers of both employment and emissions find that drivers of both have been similar (Kopidou et al., 2016; Sakai, Owen, & Barrett, 2017). The use of labour per unit of production has been decreasing, while changing input structures of production and composition of consumption has had small effects on emissions and employment. The changes in international trade structure and volume have been less important for driving global emissions relative to the other factors (Arto & Dietzenbacher, 2014), but has been a more important driver in emerging countries than in developed (de Vries & Ferrarini, 2017). Also, while changes in trade patterns did not affect GHG emissions as much as other drivers, Los, Timmer, and de Vries (2014) found that the isolated effect of international trade changes was a very strong driver for growing employment in emerging countries, while reducing employment in advanced countries. The overall patterns of drivers are also seen for most of the BRIICS countries, although with the exception of China, these countries have been much less studied, and the focus of previous decomposition analyses has mainly been on these countries' roles as producers, not consumers.

1.1. Problem description

The papers that have analysed drivers of both emissions and employment in one consistent framework are very few, and especially few are focusing on the important role of the BRIICS countries' consumption, which may have developed significantly differently from developed countries. These differences, and the growing importance of the BRIICS in the world economy and international trade, make it necessary to study these countries in more detail. Given the importance of economic growth and development in the BRIICS while reducing environmental impacts, it is important to study both aspects within one framework to identify commonalities and differences that can be addressed in policy, in this case with employment as an indicator for economic growth and development and GHG emissions as an indicator for environmental impacts.

Based on this research gap, the main research question of this thesis is:

> *What is the role of international trade and other factors in driving emissions and employment in the BRIICS countries, and what are the implications for continued development and green jobs creation?*

Which will be answered by looking into the following sub-questions:

> *How has GHG emissions and employment in production and consumption developed over time in the BRIICS?*

What patterns characterize the consumption emissions and employment of the BRIICS?

What patterns characterize the exports of emissions and employment from the BRIICS?

How did factors contribute to changes in emissions and employment in the BRIICS' consumption and exports?

To answer these questions, emissions and employment in the BRIICS' consumption and exports were calculated using multi-regional input-output (MRIO) analysis and decomposed into drivers using structural decomposition analysis (SDA). The structure of the rest of this thesis is as follows. Section two provides a literature review on drivers of emissions and employment in the BRIICS, how these have changed in recent years and the results of papers studying similar topics. Section three describes the methodology and data used in this study, and section four presents the results of the analysis. Finally, section five discusses the results and the implications of these and is followed by a conclusion.

2. Literature review

2.1. Potential drivers of emissions and employment

The growing environmental pressures today are mainly driven by human activities. Our increasing demand for consumption goods and the production of these are causing impacts like biodiversity loss, resource depletion and climate change (Rockström et al., 2009; Steffen, Crutzen, & McNeill, 2007). Human activities have pushed climate change into a zone of increasing risk of exceeding the safe operating space for avoiding irreversible changes to the Earth system (Rockström et al., 2009; Steffen et al., 2015). Still, large shares of the human population live in less developed parts of the world, with lower income-levels. These countries are expected to continue growing and reach higher standards of living and cause higher pressure on the environment. Increasing shares of global production and environmental pressures are occurring in developing and emerging countries like the BRIICS due to their growing role as producers for other parts of the world, as well as their increasing consumption as they develop (Hoekstra et al., 2016; Peters et al., 2011; Raupach et al., 2007; Y. Xu & Dietzenbacher, 2014). Continued human development in the emerging and developing countries need to be sustainable, and within the planetary boundaries for environment. This means that we need to know what factors drive human development and environmental impacts in these countries, to achieve continued growth in socio-economic aspects like employment, but not in environmental impacts like greenhouse gas (GHG) emissions.

Drivers of environmental change are often described by the IPAT relationship (Rosa & Dietz, 2012). The IPAT equation states that the environmental impact of human activities (I) is the product of population (P), affluence (A) and technology (T). Affluence and population contribute to larger volumes of consumption, and hence production and impacts. The technology of production determines the environmental impacts of a given consumption growth. Other potential drivers of emissions have also been identified in literature, for example the number of households rather than the number of people, urbanization, institutions or culture, but few studies have quantified the importance of these factors (Rosa & Dietz, 2012). Furthermore, changes in economic structure and international trade can affect environmental impacts, as the required inputs and factors of production often differ between countries, and generally the factor productivity is higher in developed countries (McMillan & Headey, 2014; Simas et al., 2015). Job creation often depends on similar factors as environmental impacts, for example economic growth and population growth that drives consumption and production and hence create more job opportunities (Kopidou et al., 2016; Los et al., 2014; Stiglitz, 2003). Technological improvements could make the use of labour more efficient while innovation and structural transformations of economies could create new types of jobs (Fankhauser, Sehlleier, & Stern, 2008; Kopidou et al., 2016; Los et al., 2014; Nübler, 2016). Opening up to trade could create more work in exports (International Monetary Fund, 2008), but jobs could also be lost in former protected sectors (Los et al., 2014; Stiglitz, 2003).

2.1.1. Development of P, A and T

a) **b)**

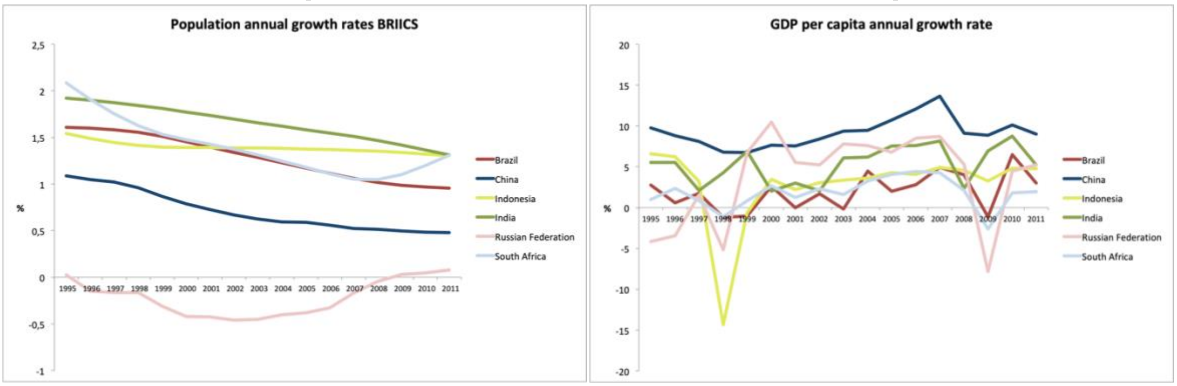


Figure 2 Growth rates of population (a) and GDP per capita (b) in the BRIICS from 1995 to 2011, from World Bank indicators (World Bank, 2019b, 2019c)

The BRIICS are home to large shares of the global population. China is currently the world's most populous country with 1.4 bn. people, followed by India, who is expected to bypass China by 2024 (United Nations, 2017b). Indonesia is the 4th, Brazil the 5th, Russia the 9th and South Africa the 25th largest country by population (United Nations, 2017b). During the period 1995 to 2011, the population growth rates among the BRIICS were highest in India and Indonesia (Figure 2). Both of these countries both have very young populations and can be expected to continue growing fast because of population momentum – the phenomenon that a large young population will still have many children in total even if the fertility rate per person decreases (Singh & Dube, 2014; United Nations, 2017a). Still, in all the BRIICS countries the population growth rates were falling in this period, as has global population growth rates (United Nations, 2017b). Among the BRIICS, Russia and China have the lowest population growth rates. Low population growth rates are associated with increasing development level and economic growth (United Nations, 2015a), and the current trends indicate that population growth may become a less important driver of impacts in the BRIICS countries as they continue developing.

During the past couple of decades the BRIICS have experienced large economic growth, making the populations more affluent and allowed them to increase their consumption levels. China is now the second largest economy in the world measured in GDP, while India is 6th, Brazil 8th, Russia 11th, Indonesia 16th and South Africa 32nd (World Bank, 2018). When normalizing GDP per population, the BRIICS countries have had relatively high growth rates (Figure 2) but are still situated much lower than developed countries. In Russia, GDP per capita was declining in the beginning of the 1990s due to the recession after the fall of the Soviet Union and the following financial crisis of 1998 (Ivakhnyuk, 2009). South Africa had declining GDP per capita in the beginning of the 1990s because of a fast-growing population along with challenges related to the apartheid era, during which time there were a number of international sanctions as well as insecure property rights and inefficient use of resources. Growth has been slow after the abolishment of apartheid in 1994 because of continued challenges, and has left South Africa with one of the highest unemployment rates in the world (Dollery & Snowball, 2003; Jones & Inggs, 2003; Rodrik, 2006a). Indonesia had high growth in GDP per capita in the beginning of the 1990s but experienced a large fall in 1997-98 when they were strongly affected by the Asian financial crisis. However, they soon managed to recover, and growth rates since have been relatively stable and almost as high as before the crisis (World Bank, 2019e). The financial crisis in 2008 led to reductions in the growth rates of GDP per capita in all BRIICS countries, and Russia was hit hardest by it (World Bank, 2019b). However, while consumption per capita growth in developed countries slowed down after the financial crisis it accelerated in the BRIICS countries, and this growth is expected to continue (Arto & Dietzenbacher, 2014).

The continued growth in consumption in the BRIICS may become a challenge for global GHG emissions. However, certain developed countries have managed to decouple their consumption growth from growth in emissions by gradually reducing their energy consumption (Akizu-Gardoki et al., 2018), which means that there may be potentials for the BRIICS to follow the same paths eventually. Also Steinberger and Roberts (2010) and Tukker et al. (2016) show that increased energy consumption is not necessarily associated with growth in human development or happiness, so reducing emissions does not necessarily cause negative consequences for continued development. While GDP per capita has become more coupled with energy use and carbon emissions over time, human development has become more decoupled from these impacts. According to Schandl et al. (2016) it is also possible to continue increasing energy use while lowering emissions, given policies promoting renewable energy investments and resource efficiency improvements.

With growing incomes in emerging economies, not only the volume of consumption may change, but also consumption patterns can shift from a relatively high importance of necessities like food, towards more carbon-intensive luxury-goods like mobility and manufactured goods which in turn can increase their environmental footprints (Hertwich & Peters, 2009; Rosa & Dietz, 2012). However, with growing incomes people may also spend more money on higher quality goods, that may last longer or be produced more efficiently, which could contribute to lower environmental impact (Girod & De Haan, 2010). The consumption in emerging economies, and particularly China, is distinguished from other countries by a relatively high importance of investments in capital formation compared to households and government consumption, because of their industrialization and building up of infrastructure (Chen et al., 2018; Minx et al., 2011; Peters, Weber, Guan, & Hubacek, 2007). This means that although the environmental impacts of consumption in emerging countries seem to be growing fast, a significant share of this increase may be due to investments that will facilitate future consumption rather than current consumption and may be temporary, or be used to produce exports rather than domestic consumption goods (Chen et al., 2018; Minx et al., 2011; Peters et al., 2007).

As countries develop, the structures of the economies also change, with consequences for their labour and energy productivities. Increased resource productivity from industrial and technological changes can reduce carbon emissions, while increased labour productivity may contribute to economic growth through higher real wages and hence increase the total labour demand of the economy, which may also contribute to innovation and creation of new jobs (Feenstra, 2007; Rodrik, 2006a). Most developed countries followed a transitional path from a high importance of agricultural employment, towards increasing shares of more productive sectors in industry and eventually services (Bah, 2009; McMillan, Rodrik, & Verduzco-Gallo, 2014). The BRIICS countries are currently in transition, although they may not follow the same paths as developed countries. China, India and Indonesia changed similarly as developed countries, first replacing agriculture by simple manufactured goods, then increasingly producing more sophisticated goods and services (Bah, 2009; McMillan et al., 2014). India has become more specialized in services and China is increasingly producing more sophisticated manufactured goods which has contributed to significant labour productivity improvements in these countries, while Indonesia are producing simpler manufactured goods than for example China, like food products and textiles and did not improve productivity to a similar extent (de Vries, Erumban, Timmer, Voskoboynikov, & Wu, 2012; Elias & Noone, 2011; McMillan et al., 2014). Brazil developed a large and diversified manufacturing sector during the import-substitution industrialization until the 1980s, but the share of industry in total value added of the economy has since decreased while services became more important (Nassif, Feijó, & Araújo, 2014; OECD, 2018). Brazil experienced decreasing labour productivity in the 1980s, but since the mid 1990s it has been growing in Brazil as well, due to improvements in the productivity of agriculture and mining, and to some extent because of reallocation of labour towards services (de Vries et al., 2012). Countries in Africa, including South Africa have to a large extent transitioned more directly from agricultural-based economies to services, rather than via the manufacturing sectors. These changes did not contribute to productivity growth before the 2000s, although they have in more recent years (Bah, 2009; McMillan et al., 2014; Rodrik, 2006a). In Russia manufacturing employment decreased after 1995, and was reallocated to mining and services, especially retail and wholesale, as well as public administration. Productivity growth of the economy however, came mainly from improvements within industrial sectors and services rather than labour reallocation (de Vries et al., 2012). This shows that while labour is usually more productive in developed countries than developing, it is increasing in all the BRIICS in relation with their economical structural changes, although they have been following various transitional pathways.

While developing countries often use more carbon-intensive technologies than advanced economies (Simas et al., 2015), also these are improving in emerging economies. China's economic growth has been heavily dependent on coal as an energy source and their energy consumption has grown fast. But as they lately have developed into a more service-based economy, the growth in energy consumption has been slowing down, while the energy mix is becoming cleaner, with lower shares of coal and growing reliance on renewables, especially hydropower, and natural gas (International Energy Agency, 2017). India is highly dependent on coal, which contributed to 56% of the primary energy consumption in 2017. They have experienced large growth in the renewable energy consumption, but also growth in coal, oil and natural gas. The energy intensity of the economy is very high, but is improving and they are becoming more efficient in the use of energy (BP, 2019a; Chakraborty, 2007). Indonesia is rich in energy resources and is a net energy exporter and the world's top exporter of coal, as well as a large producer of natural gas and biofuels. The growth in biofuel production and geothermal power, however, has led to decreasing CO_2 intensity of the Indonesian economy since 2004 (International Energy Agency, 2019b). Russia is also an energy resource rich country, and the world's largest exporter of oil and gas. The energy intensity of the Russian economy is 66% higher than the world average because their primary energy consumption consists mainly of gas, oil and coal. Renewable energy has the lowest share in energy consumption, but also the fastest growth (BP, 2019b). South Africa is one of the top producers and exporters of coal in the world, and in 2014 70% of their primary energy consumption came from coal and 23% from oil. Only 1% of their primary energy came from renewables, but the share of renewables in the energy mix is growing (Fisher & Downes, n.d.). South Africa reached a peak in the CO_2 intensity of the economy in 2004, and today's intensity is even lower than the level in the 1990s (International Energy Agency, 2019c). Brazil is one of the least carbon-intensive economies in the world, with 45% of their primary energy demand coming from renewables, especially hydropower (International Energy Agency, 2019a; Lenzen, Schaeffer, Karstensen, & Peters, 2013). This means that large shares of their CO_2

emissions come from agriculture and land-use change rather than fossil fuel combustion (Lenzen et al., 2013). However, Brazil has large offshore oil and gas reserves, and became a net exporter of oil in 2017, and these carbon-intensive exports are expected to continue growing (International Energy Agency, 2019a). These changes imply that the carbon-intensities of the BRIICS countries are improving, but there are still large potentials to reduce the carbon intensities of these economies.

2.1.2. Changes in international trade

International trade and participation in global supply chains has been an important factor for the high economic growth in the BRIICS and other emerging countries (Das, 2010; International Monetary Fund, 2008; Singh & Dube, 2014). Since the 1980s many developing countries have abandoned import-substitution industrialization to the benefit of export-led growth strategies to achieve faster economic growth and development (International Monetary Fund, 2008; Nayyar, 2016). Lower transportation costs and improved communication technologies have also made it easier for developing countries to participate in international trade (Das, 2010). The trade liberalization started later in the BRIICS than in for example "the Asian tigers" South Korea, Hong Kong, Singapore and Taiwan (Das, 2010); Brazil in 1988 (Ferreira & Rossi, 2003), India in 1991 (Alessandrini, Fattouh, Ferrarini, & Scaramozzino, 2011) and Indonesia gradually from the end of the 1980s and more accelerated in the 1990s (Feridhanusetyawan & Pangestu, 2003). China opened their markets gradually for international actors (Rodrik, 2006b) and joined the World Trade Organization (WTO) in 2001, and soon became an important producer of manufactured goods for the global market because of their low labour costs (Singh & Dube, 2014). In South Africa protectionist policies as well as sanctions from other countries during the apartheid period meant low imports and exports, but trade liberalization strategies from the 1990s eventually boosted international trade (Cassim, 2003; Edwards & Lawrence, 2008). Russia started transitioning from a central planning economy to market economy in 1991 after the fall of the Soviet Union, which included trade liberalization policies. However, liberalization was slow, and they did not become a member of the WTO until 2012 (Connolly & Hanson, 2012).

Since becoming integrated with the global market, China has been an important exporter of labour-intensive manufactured goods because of their high population and low labour costs. However, China is now increasingly exporting higher value-added goods that are more capital- and technology-intensive than labour-intensive (Caporale, Sova, & Sova, 2015; Meng et al., 2018; Pan et al., 2017; Rodrik, 2006b; Singh & Dube, 2014). Brazil initially exported manufactured goods but lately transitioned towards exporting more minerals, metals and agricultural goods like soy, sugar and beef, becoming more emission-intensive and relying on lower value-added export goods (Kingstone, 2012). After trade liberalization, India transitioned from agricultural exports towards more service-based exports, especially modern services like communication and business services (Alessandrini et al., 2011; Goswami, Gupta, Mattoo, & Sáez, 2012). Russia, on the other hand, mainly exports energy resources like oil and natural gas, although exports of services and other non-oil goods have started growing slightly in importance (Das, 2010; Singh & Dube, 2014; World Bank Group, 2018). South Africa is largely exporting minerals, but has lately launched a strategy to promote more diversified exports, especially of goods and services of higher value-added (Department of Trade and Industry, n.d.; Singh & Dube, 2014). Indonesia historically exported mainly agricultural goods, but is now a large exporter of coal, palm oil, petroleum as well as manufactured goods (Elias & Noone, 2011). The exports of most of the BRIICS are thus becoming increasingly sophisticated and more service-based, contributing to generating employment and value added, although several of them are still highly dependent on energy-intensive exports.

Patterns of international trade are also in change. Traditionally production has been outsourced from developed countries to emerging countries like the BRIICS. However, as the emerging economies are growing, they are becoming more important as global consumers and are outsourcing labour-intensive production-stages to other developing countries. They are therefore important drivers of growth and structural transition from agriculture to manufacturing in the developing world (Canuto, Haddad, & Hanson, 2010). According to Meng et al. (2018), we are now in a new phase of globalization, where the trade between developing countries are becoming much more important for global emissions than trade from developing to developed countries. Especially China and India are outsourcing production stages intensive in labour and raw materials to even poorer developing countries (Meng et al., 2018; Nayyar, 2016). Companies in developed economies are no longer looking to China for the most labour-intensive production-stages because of increasing labour-costs, but rather to countries such as Indonesia, Bangladesh or Vietnam (Meng et al., 2018). China has also become one of the most important trading partners for the other BRIICS countries and the share of intra-BRIICS trade in total trade of each country is growing (Singh & Dube, 2014). This means that global supply chains and their associated emissions are becoming even more fragmented and complex, and can make emission reductions more challenging (Meng et al., 2018). The changing locations of production may also affect global emissions and employment, if the new production locations are more or less intensive in emissions or employment. These changes reflect the growing importance of studying the impacts of international trade with a perspective on emerging countries as consumers, not just as sources of production for the developed world.

2.2. Contributions of drivers to emission growth

Based on the IPAT equation, the importance of the different drivers have often been identified using the "stochastic impact regression on population, affluence and technology" (STIRPAT) model, which allow the variables to have different effects on the impact rather than proportional (York, Rosa, & Dietz, 2003). This method has allowed testing for the importance of the three factors in the IPAT equation, and also additional factors that can be relevant drivers of environmental impacts, such as urbanization, trade openness and industrialization (York et al., 2003). A drawback of this method is that studies using different model formulations have found quite various results (Wei, 2011). For example, York et al. (2003) found that population growth had a proportional effect on global emissions, while Shi (2003) found that it had a much more than proportional effect on emissions and Jorgenson and Clark (2013) found population to be the most important driver of emissions, while York et al. (2003) and Fan, Liu, Wu, and Wei (2006) found that affluence has been the most important driver of emissions. In addition, the econometric models have a residual term, so they are not able to explicitly account for all changes in the impacts (Kopidou et al., 2016; York et al., 2003). Further, this method only addresses the direct production emissions of a country, rather than the drivers of its consumption emissions, and has not been used for analysing drivers of employment or other social indicators.

Decomposition analysis is another approach for attributing importance to the different drivers, and these methods have been used for both environmental and social indicators. The two most used decomposition techniques are index decomposition analysis (IDA) and structural decomposition analysis (SDA) (Feng, Davis, Sun, & Hubacek, 2015; Hoekstra & van den Bergh, 2003; Su & Ang, 2012; Wang, Ang, & Su, 2017). They are based on similar principles and methodologies, but differ in the underlying data and hence the effects covered (Wang et al., 2017). In both frameworks, the isolated effect of each driver on the impact is the determined, given that all other factors are kept constant – the *ceteris paribus* condition. IDA is often based on aggregated sector-level data and used to study drivers of impacts in a certain sector of the economy, while SDA is based on input-output data and used to study the interrelationships of the supply chains producing consumer goods (Hoekstra & van den Bergh, 2003; Su & Ang, 2012). This means that IDA requires less data, is easier to calculate over time and for several countries, and is a very transparent method, while SDA requires more data, but allows for more detailed analysis, covering interdependencies among sectors and full supply chain effects of consumption (Feng et al., 2015; Hoekstra & van den Bergh, 2003; Su & Ang, 2012).

While results of papers using STIRPAT to determine the importance of drivers have given various results, decomposition analyses, both IDA and SDA, at different spatial scales and time series have generally found consistent results, which suggest that these methods may be more consistent and appropriate for analysing contributions of drivers. For example Malik and Lan (2016), de Vries and Ferrarini (2017), Hoekstra et al. (2016) and Arto and Dietzenbacher (2014) using SDA, and Yao, Feng, and Hubacek (2015) and Kopidou et al. (2016) using IDA, all find that for most countries growth in GHG emissions has mainly been driven by growing per capita consumption along with growing populations, but that the growth in emissions has been slowed by technological improvements, like reduced carbon intensity of energy and reduced energy intensity of production. These patters were also found for China, India, Indonesia and Brazil, with consumption, particularly domestic, being the most important driver of territorial emissions, and the effect being offset by carbon intensity improvements of production (de Vries & Ferrarini, 2017).

Changes in the international trade structure, by outsourcing of production to developing countries, has contributed to growth in global emissions between 1995 and 2008, but the effect has been less important than the other factors (Arto & Dietzenbacher, 2014; Hoekstra et al., 2016). Hoekstra et al. (2016) find that 18% of the global CO_2 emission growth from 1995 to 2007 was driven by countries replacing domestic production with imports from countries with higher CO_2 intensities than their own production. The most important drivers of the emissions embodied in international trade have been similar to those of global emissions, with growing consumption driving growth in emissions and technology improvements reducing that effect. These effects were quite similar across countries, while differences in growth in emissions embodied in trade in developed and developing countries were related to the changes in international trade structure with growing outsourcing to developing countries (Y. Xu & Dietzenbacher, 2014). Although not as important as the growth in consumption and the technological improvements for global emissions, it is clear that changes in the structure of international trade and production has been a contributor to growth in emissions in emerging countries and should be considered in decomposition analyses.

2.2.1. Decompositions of emissions in the BRIICS

The activities of the BRIIC countries have become important drivers of global emissions since the 1990s (Arto & Dietzenbacher, 2014). Among the BRIICS, China is the country that has been most studied using decompositions analyses. A literature review by Su and Ang (2012) found that 40% of SDAs of energy or emissions between 1999 and 2010 were covering China and/or Japan. Mainly, papers find that in China, technology improvements had a stronger effect over time, reflecting faster technology improvements, but these have still been more than offset by consumption growth (de Vries & Ferrarini, 2017; Guan, Peters, Weber, & Hubacek, 2009; Peters et al., 2007). However, with the combined effects of technology improvements in China and lower global demand due to the financial crisis, emissions in trade from developing to developed countries declined between 2007 and 2012 (Pan et al., 2017). During the 1990s, exports demand from abroad was the most important consumption category driving the growth in production emissions in China, but from around the beginning of the 2000s, capital investments and household consumption became more important consumption categories than exports (Minx et al., 2011; Peters et al., 2007), reflecting a growing importance of China's domestic consumption for generating emissions. In the exports of China, M. Xu, Li, Crittenden, and Chen (2011) found that the most important driver of CO_2 emissions between 2002 and 2008 was the composition of their exports, because of a growing share of metal products. On the other hand, Pan et al. (2017) identified the volume of exports as a much more important driver of CO_2 emissions embodied in exports than the composition. Further, both found an important role of reduced carbon intensity of production in lowering China's exported emissions.

In Brazil, the emission intensity of production was a strong driver of growth in CO_2 emissions in their consumption from 1970 to the end of the 1990s, but has since been improving and contributed to offsetting emissions (Lenzen et al., 2013). The growth in energy intensity has mainly been caused by land use change for the agricultural sector. Population growth became an important driver of carbon footprints in Brazil from around 1980, while the increased consumption per capita has been an important driver of emissions since around 1990, around the same time when emission intensity and production structure started improving (Lenzen et al., 2013). Population growth had the largest cumulative effect on emissions throughout the period 1970 to 2008 but is expected to become less important in the future. Growth in consumption was negative in the 1980s, but then started growing and had a stronger effect than population growth in the later periods (Lenzen et al., 2013).

For India, Paul and Bhattacharya (2004) identified the contributions of drivers of CO_2 emissions from energy use in three of India's sectors between 1980 and 1996. Economic growth had the largest effect on emission growth, while energy intensity improvements contributed to lowering industrial and transport emissions. Chakraborty (2007) used SDA to study drivers of the growth in India's energy consumption between 1993-94 and 1998-99. The most important drivers were increased energy intensity as well as changes in the structure of the economy towards more use of energy-intensive intermediate goods, showing that the improvements in energy intensity found by Paul and Bhattacharya (2004) for two economic sectors does not apply to the economy as a whole. Increased final demand for energy also contributed to growth in energy consumption, although less importantly than the technological changes. These changes in technology were related to India's transition from an agricultural towards a more industrialized and urbanized economy, which caused energy intensity of GDP to increase, especially because there were few policy incentives in place to encourage upgrading to energy efficient infrastructure. However, de Vries and Ferrarini (2017) found that emission intensities of India's production improved between 1995 and 2008 and contributed to lowering emissions, implying that the energy used became less carbon-intensive, and energy use became more efficient in more recent years.

The changes in CO_2 emissions in former Soviet states, including Russia, were analysed by Brizga, Feng, and Hubacek (2013) using IDA, covering the period 1990 to 2010. For all of the former Soviet states the collapse of the union led to decreased affluence and economic activity which reduced their CO_2 emissions between 1990 and the beginning of the 2000s. In the same time period, population in the region was decreasing and lowering emissions further, while energy intensity of the economy was increasing and contributed to increasing emissions. In the 2000s the region experienced economic growth and increasing energy efficiency, patterns more similar to other regions. Similar result were found by Lan and Malik (2013) using SDA to decompose changes in Russia's energy consumption between 1990 to 2000 and Malik and Lan (2016) decomposing Russia's carbon footprint between 1990 and 2010 – losses in incomes and consumption and changing production structures reduced energy consumption and production emissions in the beginning of the 1990s. Outsourcing of production to other countries contributed further to reducing the growth of Russia's territorial emissions, similar to the results found for most developed countries. Still, their territorial emissions between 1995 and 2008 increased because of increased consumption, especially domestic but also of exports, in the end of the period (de Vries & Ferrarini, 2017).

The decreasing affluence in South Africa after the abolishment of the apartheid system contributed to lowering the carbon footprint between 1995 and 2000. Still, the total emissions increased over the period 1990 to 2010, because of growing affluence in more recent years, as well as higher carbon intensity of production and increasing population (Malik & Lan, 2016). Also the drivers of South Africa's CO_2 emissions from coal-sourced electricity production have been analysed (Beidari, Lin, & Lewis, 2017), as well as the drivers of the growing electricity consumption of selected sectors (Inglesi-Lotz & Blignaut, 2011), industrial energy consumption (Olanrewaju, 2018) and changes in energy efficiency (Inglesi-Lotz & Pouris, 2012). The most important findings are that economic growth has been driving growth in emissions, electricity and energy consumption and the energy efficiency of the South African economy improved, but structural changes contributed to slowing the energy efficiency improvements by shifting towards more carbon-intensive sectors.

Drivers of emissions in Indonesia have been less analysed than in the other BRIICS countries, and mainly covering only parts of the economy. One example is Kurniawan, Sugiawan, and Managi (2018) analysing the drivers of CO_2 emissions from energy consumption in households from 2000 to 2015 using the IDA approach. The energy consumption increased because of growth in the population as well as incomes. Changes in the fuel mix, mainly from kerosene to liquefied petroleum gas (LPG), contributed slightly to reducing the direct emissions in peoples' homes, while the decreasing share of coal in the electricity mix contributed to lowering indirect emissions from household energy consumption. An IDA of the production CO_2 emissions in Indonesia from 1980 to 1998 shows that the total emissions were growing, mainly because of growth in per capita GDP, population and energy intensity of the economy. The growth was slightly offset by reductions of the fossil fuel share, and reduced CO_2 intensity of the fossil fuels, reflecting a switch to slightly less polluting fuels (Lee & Oh, 2006). Growth in the production emissions in Indonesia between 1995 and 2008 were driven by growing consumption levels domestically and demand for exports, as well as relocation of production to Indonesia, while improvements in technology slightly reduced the growth (de Vries & Ferrarini, 2017).

2.3. Contributions of drivers to employment growth

SDA and IDA have been widely used for studying drivers of emissions and energy use, but less used for studying the drivers of social or economic impacts like employment. Still, a few papers have used decomposition analysis to study the common drivers of emissions and employment. For five EU countries, Kopidou et al. (2016) using IDA find that economic growth has been the most important driver of both emissions and employment in these countries' industrial sector, while the emission and employment intensities of production offset both indicators. Structural changes, in terms of shares of output from various industries, contributed to some reductions in both emissions and employment, as sectors with lower carbon- and labour-intensities became more important. Sakai et al. (2017) using SDA find similar results for the drivers of emissions and employment in the UK's consumption and production. The UK managed to reduce their production emissions while increasing the amount of jobs in production, because the reduced emission intensity of production had a stronger effect than the reduced employment intensity and the growth in output. Still, in their consumption emissions and employment both continued to grow because of stronger growth in demand. Simas, Hertwich, and Wood (2018) also find similarities for drivers of carbon emissions, energy use and employment footprints for the BRIICST (including Turkey). Growth in consumption drove all footprints, while efficiency gains in production contributed to slightly offsetting the consumption growth, more strongly for the employment footprints. Changes in international trade were important for offsetting the growth in footprints in several of the countries in the group, unlike for more developed regions where trade mainly contributed to growth in footprints due to outsourcing of production to more carbon-intensive regions. The consumption and structural changes in the BRIICST contributed more strongly to growth in emissions than in employment. All these analyses suggest that employment and emissions development follow similar patterns, driven by similar underlying factors, but these drivers are often causing faster growth in emissions than in jobs.

Drivers of global employment by different skill levels from 1995 to 2008 for 41 countries was studied using SDA by Los et al. (2014). Also this paper found that growth in consumption volume was the most important driver of growth in total employment, while technological changes in terms of employment intensity of production reduced the demand for employment. In most developed countries the relocation of production from developed to developing countries contributed to lowering employment, while it contributed significantly to increasing the number of jobs in most emerging countries. International trade has affected the quality of jobs in emerging countries as well, as developed countries are specializing in higher-skilled jobs, while lower-skilled jobs are outsourced to developing and emerging countries. In China the effect of growing demand for exports on their production employment was completely offset by productivity gains between 1995 and 2000. However, from 2001 to 2006 the exports demand boomed and contributed to a significant amount of job creation, most of these jobs low-skilled. Since 2006 domestic demand has been more important than foreign demand for generating jobs (Los, Timmer, & de Vries, 2015), which again highlights the growing role of the domestic consumption in

China. Thus, international trade changes have been important for growth in employment in developing countries, but especially in low-skilled jobs.

Changes in employment and labour productivity was decomposed into sector contributions in different countries, including China, India, Indonesia and Brazil, by Roncolato and Kucera (2013). The results show that structural transition of the economies is important for employment growth. While agriculture is an important employer in the emerging countries still, China experienced large employment and productivity growth in service sectors and in construction, while Brazil, India and Indonesia services and manufacturing was important for growth in employment and productivity. Services are labour-intensive, and often more productive than other sectors, especially agriculture. Thus, this transition to more service-based economies can contribute to important employment gains as well as economic growth. At the same time, manufacturing was also important for the employment growth, which might cause larger growth in emissions as well, compared to the growth in services.

2.4. Further research on green jobs

The BRIICS countries are producing more sophisticated goods, becoming more efficient in their production, more integrated with the world market and most importantly are experiencing high economic growth. Still, they are not catching up with the developed countries' development and income levels yet. It is clear that growing consumption has been the main driver of growing emissions and employment in most countries, while technologies are improving, but not enough to offset the emission growth. Changes in international trade patterns has had a relatively low effect on changes in emissions in global impacts, compared to other factors like consumption growth and technological improvements, but has shifted emissions from developed to developing countries, so it has been an important driver at the country level. Changes in international trade have also been important for job creation in emerging countries, but to a large extent contributing to creating low-skilled jobs. Drivers of employment have been quite similar, with consumption growth contributing to labour growth, while productivity improvements reduced the need for labour inputs per unit of output. A challenge for green job creation is that the drivers are contributing to faster growth in emissions than in employment, increasing the emission intensities of each job.

The decomposition analyses of the BRIICS' emissions so far have shortcomings, and analyses of drivers of employment in the BRIICS are very few. The most important short-coming is that most studies of the BRIICS focus on only their production impacts, or even just impacts in selected sectors of the economy, neglecting the important role of the BRIICS also as consumers and the effect of changes in international trade. Several of the papers only compare changes between two points in time, rather than in time-series, so they may miss out on important patterns over time and risking that the two years compared are years of uncommon economic events, not representative for a longer time period.

Because of the growing role of the BRIICS as consumers, and the importance of international trade for generating global emissions and employment, it is useful to analyse green jobs and their drivers based on multi-regional input-output analysis. This allows accounting for full supply chain emissions and employment, reallocating the environmental or social impacts in production of goods and services to the final consumers of these (Peters, 2008). Hence, the greenness of a job in producing a good would depend on all emissions and employment occurring in the full supply chains of the production, rather than for example in certain production locations. This approach would also hold the consumers responsible for all impacts occurring due to the production of their consumption goods. International climate agreements are currently based on production-based emissions, but the use of consumption-based commitments are argued for, as this would help in avoiding carbon leakage – achieving emission reductions by outsourcing production to other countries with no commitments, and holding the countries responsible for the impacts driven by their consumption (Peters, 2008). The current availability of input-output data at full time series can also improve earlier studies by covering full time-series. Further, input-output tables are now more commonly covering social impacts as well as environmental impacts, allowing to analyse drivers of employment and emissions in one consistent framework to identify important commonalities and differences in the drivers of employment and emissions over time and contribute to more knowledge on how to achieve green jobs.

3. Methodology

3.1. Input-output analysis

Multi-regional input-output (MRIO) analysis was used for calculating the labour and emissions of production in the BRIICS countries, and in the supply chains of the BRIICS' consumption. Input-output (IO) analysis is a methodology developed in the 1930s by Vassily Leontief. A set of linear equations are used to analyse the interrelationships between different sectors of the economy. These are based on symmetric input-output tables, which show all the monetary flows between industries of the economy in a given year (Miller & Blair, 2009, pp. 1-2). The input-output tables are derived from supply-use tables, which show how different industries and final users use and produce different products (Beutel, 2008). Since the late 1960s, the methodology has been extended with environmental accounts, and later also social accounts, to identify the environmental and social impacts occurring as a consequence of economic activity (Miller & Blair, 2009, pp. 1-2; Polenske, 2004).

	Industry or goods (destination)	Final demand	Total output
Industry or goods (source)	$Z = \begin{pmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{pmatrix}$	$y = \begin{pmatrix} y_1 \\ \vdots \\ \vdots \\ y_n \end{pmatrix}$	$x = \begin{pmatrix} x_1 \\ \vdots \\ \vdots \\ x_n \end{pmatrix}$
Value added	$V = (v_1 \cdots \cdots v_n)$		
Total input	$x = (x_1 \cdots \cdots x_n)$		

Satellite accounts	$F = \begin{pmatrix} f_{11} & \cdots & f_{1n} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mn} \end{pmatrix}$

Figure 3 - Simplified input-output table of an economy with n industries

Figure 3 illustrates a simplified input-output table. The **Z** matrix in is the inter-industry matrix. It has the dimensions industries by industries, and each element $\mathbf{z_{ij}}$ in the matrix shows the flows of inputs from industry *i* to industry *j*. The rows in the **Z** matrix show the distribution of each industry's output to other industries, and the columns show how much input each industry needs from other industries to produce its total output. The diagonal of the inter-industry matrix, where *i*=*j*, shows how much input each industry requires from its own production (Miller & Blair, 2009, pp. 11-13). The **Y** vector in Figure 3 shows the final demand from each of the *n* industries of the economy. While displayed as a vector in Figure 3, it can also be a matrix, showing the final demand for each industry's production by different consumers, like households, governments or capital formation. The **Z** and **Y** represent all production needed for intermediate production and final consumption, and sums to **x**, the vector of total output from each of the *n* industries (Miller & Blair, 2009, pp. 11-12). Each element $\mathbf{x_i}$ in **x** is the total output of industry *i* for intermediate production and final demand:

$$x_i = z_{i1} + \cdots + z_{in} + y_i \tag{1}$$

The **V** vector represents the value added, or non-industrial inputs, in each industry's production. While displayed as a vector in Figure 3, also this part of the IO table can be a matrix, including different categories of value added, like labour, imports or capital depreciation (Miller & Blair, 2009, p. 3). The inputs in the **Z** matrix and the value added in **V** adds up to total input in the economy, which equals total output, **x** (Miller & Blair, 2009, p. 15). **F** is the satellite account, and shows the total impacts of each indicator *m* for each of the *n* industries' production (Miller & Blair, 2009, p. 24). These could be environmental extensions with indicators like emissions of various pollutants or energy consumption, or social accounts with indicators like employment at different skill levels or genders. All values in the IO table, except those in the satellite accounts, are usually in monetary units. This means that each industry's output are average products rather than actual products. In reality each industry may produce several different products with different requirements and impacts, meaning that the analysis is not suitable for very detailed product analyses, but rather more suitable for analyses at the macro-economic scale (Kitzes, 2013; Tukker et al., 2016).

3.1.1. Solving the model

As seen in Figure 3, the intermediate demand and final demand sums up to total output of the economy. This is illustrated in matrix notation in equation (2), where *i* is a summation vector containing only 1s, with dimensions sectors by 1, used to sum the **Z** matrix:

$$Zi + y = x \tag{2}$$

In IO analysis, it is assumed that the required inputs of production for each sector depend directly on the amount of output produced in that sector, in fixed relationships (Miller & Blair, 2009, pp. 15-16). Therefore, the matrix of required inputs per unit of production, **A**, is found by dividing intermediate inputs **Z** by total output **x** as in equation (3). $\hat{\mathbf{x}}$ is the diagonalized **x** vector, allowing to divide each input of sector *j* by the total output of sector *j*.

$$A = Z\hat{x}^{-1} \tag{3}$$

The **A** matrix has the same dimensions as the **Z** matrix, and each element of the **A** matrix, $\mathbf{a_{ij}}$, is the technical coefficients that states how much inputs is required by each industry *j* from each industry *i* to produce one monetary unit of output (Miller & Blair, 2009, p. 16):

$$a_{ij} = z_{ij}/x_j \tag{4}$$

By solving the model in equation (3) for **x**, it can be used to calculate impacts associated with full supply chains producing for final consumption. First, rearranging equation (3) gives:

$$Zi = Ax \tag{5}$$

Inserting for **Zi** from equation (5) in equation (2) gives:

$$x = Ax + y \tag{6}$$

Solving equation (6) for **x** gives:

$$x = (I - A)^{-1}y = Ly \tag{7}$$

I is an identity matrix with the same dimensions as **A** and containing 1s on the diagonal and zeros otherwise. **L = (I–A)$^{-1}$** is the Leontief inverse, or the total requirements matrix. The term reflects the full supply chain requirements for producing one unit of final demand, and can be used to calculate the full supply chain impacts of producing final output (Miller & Blair, 2009, pp. 20-21).

To calculate the impacts from producing final consumption goods, the impacts per unit of production, **S** is needed. It is found by dividing total impacts **F** by total output **x** (Kitzes, 2013):

$$S = F\hat{x}^{-1} \tag{8}$$

The supply chain impacts of producing final demand, **Q**, are found by multiplying the impacts per unit, **S**, with the total requirements per unit of final demand, **L**, and the final demand, **y**, as in equation (9) (Kitzes, 2013):

$$Q = SLy \tag{9}$$

Equation (9) gives the total impact of each indicator. To get results with details on which sector of production the impacts occur in, here called the production approach, we can diagonalize the **S** matrix:

$$Q_{production} = \hat{S}Ly \tag{10}$$

To rather have the results given for full supply chain impacts for each good of final consumption, or footprints, we diagonalize the final demand **y**:

$$Q_{consumption} = SL\hat{y} \tag{11}$$

Average annual growth rates of the impacts over the time series were calculated by:

$$\frac{Q_{end\ year} - Q_{start\ year} / Q_{start\ year}}{nr\ of\ years} \tag{12}$$

3.1.2. Multi-regional input-output analysis

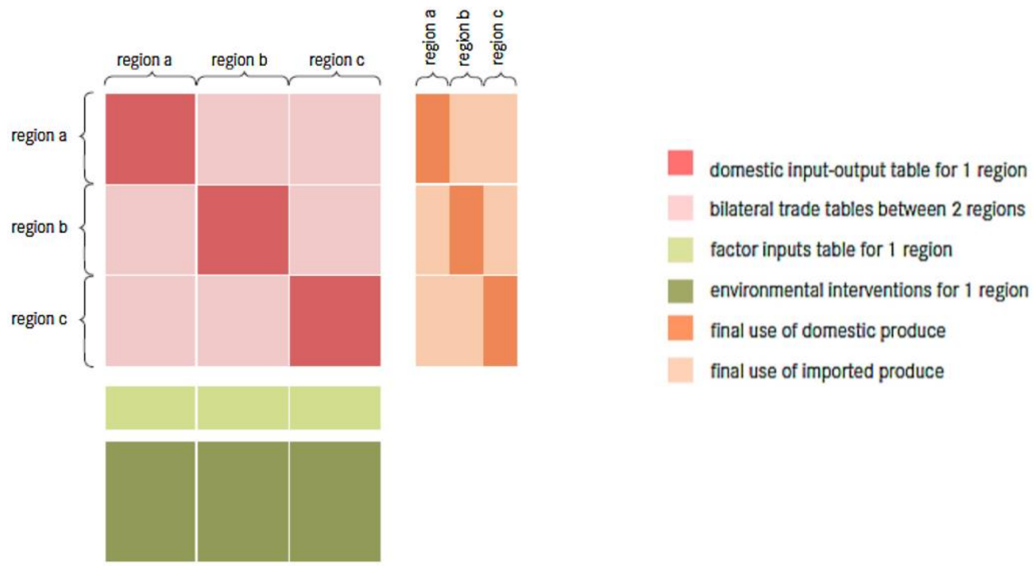


Figure 4 - Illustration of a multiregional input-output table with three regions a, b and c from Tukker et al. (2016)

To analyse the relations of sectors across countries, to also account for impacts embodied in international trade, domestic input-output tables of several regions can be connected in a multi-regional input-output (MRIO) model as shown in Figure 4 for three regions. This model represents the flows from each industry in each region to each industry and consumer in each region. The diagonal part of the MRIO table is the domestic tables, with flows between industries within the same region, while the off-diagonal part shows flows traded between industries in different regions. The off-diagonal part is usually derived based on assumptions on import shares, because the international trade statistics usually do not contain data on how imports from various industries are distributed on domestic industries, so these parts of the MRIO table can be more uncertain than the domestic parts (Lenzen, Pade, & Munksgaard, 2004; Peters, 2007). Calculations of impacts in MRIO follow the same approach as described above for a single region. The impacts of the BRIICS countries are calculated both from the consumption approach and the production approach described above, and from the production approach the impacts in exports are identified. The consumption approach includes the impacts in domestic production for domestic consumption plus the emissions in imports, while the production approach includes the domestic emissions for domestic consumption plus emissions in exports.

3.2. Structural decomposition analysis

Structural decomposition analysis (SDA) was used to analyse how different determinants contributed to changes in impacts in consumption and exports over time. The change in impact, Δ**Q,** from year 1 to year 2 is the impacts in year 2 minus the impacts in year 1:

$$\Delta Q = Q_2 - Q_1 = S_2 L_2 y_2 - S_1 L_1 y_1 \tag{13}$$

The changes in impacts can further be decomposed into the changes in each of the determinants. The changes in each determinant, denoted by Δ, equals year 2 value of the determinant minus the year 1 value:

$$\Delta S = S_2 - S_1 \tag{14}$$
$$\Delta L = L_2 - L_1 \tag{15}$$
$$\Delta y = y_2 - y_1 \tag{16}$$

These relationships give the possibility to rearrange equation (13) in several ways to decompose the changes in impacts into the changes in determinants (Miller & Blair, 2009, pp. 593-595). Equations (17) and (18) show two possibilities, called the "polar decompositions" because the weighting of the variables between year 1 and 2 are changed from one end of the equations to the other (Dietzenbacher & Los, 1998).

$$\Delta Q_1 = \Delta S L_1 y_1 + S_2 \Delta L y_1 + S_2 L_2 \Delta y \tag{17}$$

$$\Delta Q_2 = \Delta S L_2 y_2 + S_1 \Delta L y_2 + S_1 L_1 \Delta y \tag{18}$$

The first term in the decompositions in equations (17) and (18) reflect the isolated contribution of changes in intensities of production, the second term reflect changes in the input structures of sectors and the third term changes in final demand. The yearly weights do not necessarily have to be changed in this order. With *n* determinants, the possible number of decompositions are *n!,* and none of the forms are preferred over the others (Dietzenbacher & Los, 1998). The recommended solution to this challenge is taking the average of all possible decompositions (Dietzenbacher & Los, 1998). This can be very time consuming if there are a large number of determinants, and the results can be very similar to the optimal solution by just finding the average of the two "polar" decompositions in equations (17) and (18), as shown in equation (19) (Dietzenbacher & Los, 1998). This is the approach used in this thesis, often referred to as the D&L98 method.

$$\Delta Q = \frac{(\Delta Q_1 + \Delta Q_2)}{2} \tag{19}$$

Another possible approach to use within SDA is the Logarithmic Mean Divisia Index (LMDI) method. The main benefit of choosing the D&L98 method over LMDI is the possibility to further decompose the structure effect (**L**) into sub-effects (Su & Ang, 2012), which is done in this analysis. The results of the structural decomposition show the isolated effect of each determinant - how much changing one of the determinants at the time would have changed the impact, holding the others constant, from one year to the next. The results are given for each country, determinant and pair of years. The results might have been slightly more accurate with the full decomposition, but using the average of the two polar decompositions should provide very similar results and the patterns found with this approach can be assumed to be certain even if some values might have changed using the full set of decompositions (Dietzenbacher & Los, 1998).

While the results display the isolated effect of changes in one determinant, the different determinants might depend on each other to change. For example may the changes in production structure be related to the changes in consumption patterns or changes in trading relationships, and intensities of sectors may change as a consequence of changes in input structures. This means that the results for each determinant may not reflect all relevant changes, because some of those changes in one determinant might not have occurred without changes in another one (de Vries & Ferrarini, 2017; Dietzenbacher & Los, 2000).

3.2.1. Decomposition of exports

The decomposition of the impacts in exports was based on the emissions embodied in bilateral trade (EEBT) approach, rather than MRIO, which calculates the exported impacts irrespective of whether the exports are used for intermediate or final demand (Peters, 2008). The same approach has also been used by for example the Organization for Economic Co-operation and Development (OECD) to calculate trade in value added and trade in employment (OECD, n.d.). While this approach does not cover the full supply chain impacts of consumption like the MRIO approach, it is useful because the results are closely linked to actual bilateral trade data and can be helpful for the BRIICS countries to implement policies that target impacts in their export production (Peters, 2007). The calculations are similar to MRIO, but only the domestic parts of the **S** and **L** matrices are used to calculate impacts, so we only cover the domestic requirements and domestic impacts. The final demand used to calculate the impacts in exports is the sum of the demand from all other countries for both final goods and inputs for production. The demand for final goods in other countries are the off-diagonal parts of the final demand matrix in the MRIO model, while the demand for inputs into production in other countries are the off-diagonal parts of the inter-industry matrix in the MRIO model. Impacts embodied in exports from country *r*, $\mathbf{Q^{ex}_r}$, is then (Peters, 2007):

$$Q^{ex}{}_{r} = S_r L_{rr} \sum_s e_{rs} \quad (20)$$

Where $\mathbf{S_r}$ is the emissions per unit of output for the sectors in country *r*, $\mathbf{L_{rr}}$ is the required inputs for domestic producers in country *r* from each producer in country *r* and $\mathbf{e_{rs}}$ is the demand for exports from country *r* to country *s*.

3.3. Data and indicators

3.3.1. Database

The data used in this analysis are MRIO tables from the database EXIOBASE 3, version 3.6. This database is available for the full time series 1995 to 2011 and has a high industry and country resolution, covering 200 products and 163 industries, 44 countries and 5 rest of the world (ROW) regions (Stadler, Wood, et al., 2018), where the product by product resolution was used in this thesis. The database makes it possible to cover changes in the footprints and their determinants from one year to the next, rather than just between two points in time, and structural changes of the economies can be analysed because of the high product and sector resolution and a specific focus on capturing such changes in the database. EXIOBASE 3 also includes detailed satellite accounts with a large range of environmental and social indicators, which makes it suitable for sustainability analyses of social and economic aspects, like jobs, as well as environmental impacts (Stadler, Wood, et al., 2018).

The database is covering the EU and its major trading partners and other large world economies, but are covering fewer developing countries (Stadler, Wood, et al., 2018). This means that while it is possible to analyse the BRIICS countries' relations with large developed economies, most developing countries are aggregated into ROW regions, so EXIOBASE 3 does not allow to analyse the trade relations between the BRIICS and most other developing countries. Further, the data for developing countries are more uncertain than developed countries because of less access to data, and many of the are aggregated into large rest of the world (ROW) regions, which adds another uncertainty to the results linked to these regions, as many countries with different production structures and technologies are aggregated (Simas, 2018). The impacts in the BRIICS' consumption and production are calculated with the current price version of EXIOBASE 3, while the SDA on the other hand is performed using IO tables deflated to previous year prices, because it is important that the changes in determinants only reflect real changes, not inflation (Stadler, Bulavskaya, Södersten, Schmidt, & Wood, 2018).

3.3.2. Indicators

The impacts studied are GHG emissions and employment. The GHG indicator includes emissions from fossil fuel combustion and other industrial activities like cement production, as well as waste treatment and agriculture, but does not include GHG emissions from land use change (Kuenen, Usubiaga, Acosta-Fernández, & Merciai, 2018). In terms of gases, the indicator for GHG emissions includes the emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFC) and perfluorocarbons (PFC) (Stadler, Wood, et al., 2018). Based on their global warming potential relative to CO_2 on a 100 year time horizon (GWP100) these emissions are characterized to a common unit, kg CO_2 equivalents (IPCC, 2014, p. 87). This is done by multiplying the emissions with the characterization factors displayed in Table A 2, which also shows which emissions are included in the analysis. The emission data in EXIOBASE was collected from the International Energy Agency (IEA) energy balances and other international statistical databases and modelled to be aligned with the EXIOBASE level of detail. The modelling implies that emissions at country and sector scale are more uncertain than total global emissions. Data for non-combustion emissions in developing countries were often not available or of poor quality, meaning that it had to be estimated, and are therefore more uncertain than developed countries.

The employment indicator measures the total number of persons working within each sector, including self-employed persons, and is measured in person-year-equivalents (Stadler, Wood, et al., 2018). The indicator is based on labour statistics from the ILO, OECD and Eurostat, but these statistics are not available at such a high product and industry resolution as EXIOBASE, meaning that the data had to be disaggregated from broad sectors to the more detailed industries of EXIOBASE (Simas, Stadler, & Wood, 2018; Stadler, Wood, et al., 2018). This disaggregation adds an uncertainty to the sector-level employment data, which is especially high for developing countries which were less covered in the statistics and therefore more based on estimates (Simas, Stadler, et al., 2018).

3.3.3. Determinants

The main determinants of changes in emissions and employment in IO models are **S**, **L** and **y** as described in equation (9). Each of these can again be split into several determinants to provide more detailed results (Miller & Blair, 2009, p. 598). The determinants for impacts in consumption and in exports used in this thesis are presented in Table 3-1.

CONSUMPTION		**EXPORTS**	
S	Changes in carbon- or labour intensity of production	$\mathbf{S_r}$	Changes in carbon- or labour intensity of production domestically
H	Changes in input structure of production	$\mathbf{L_{rr}}$	Changes in the domestic input structure of production
T	Changes in source country of inputs	$\mathbf{Y_{volume}}$	Changes in the volume of exports
YH	Changes in the composition of products in final demand	$\mathbf{Y_{comp}}$	Changes in the composition of products in exports
YT	Changes in trading partners for final products		
y	Changes in consumption per capita		
P	Changes in population		
$\mathbf{F_{hh}}$	Changes in direct emissions from households		

Table 3-1 – Determinants of impacts in consumption and exports

S is the matrix of labour and GHG emissions per unit production of each product. Changes in **S** can be interpreted as changes that make the production more or less labour- or carbon-intensive. In the consumption approach changes in **S** reflect changes occurring anywhere in the supply chain for consumption, while in the exports approach only changes in the domestic technologies, $\mathbf{S_r}$, are considered. Changes in **L** reflect structural changes of the economies, where different industries may require different combinations of inputs over time to produce one unit of final demand. In the consumption approach, this determinant is split in two parts: **H** which describes the changes in the input structure of the production of a good, irrespective of what countries the inputs come from, and **T** which reflects the changes in trading partners the inputs are sourced from. In this way we are able to analyse whether impacts from changes in input structures are mainly due to changing technologies (**H**) or changes in international trading patterns (**T**). The **H** is derived by summing the technology matrix **A** over the countries, so we get a matrix with the requirements of industries irrespective of what countries the industries are located in. The **T** is derived by dividing the **A** matrix by **H**, giving a matrix showing what share of each input is sourced from what region. In the exports approach we are only considering the domestic requirements, $\mathbf{L_{rr}}$, therefore it is not relevant to split the determinant in two when considering the drivers of impacts in exports.

For the consumption approach, changes in final demand are split into consumption per capita **(y)**, changes in population **(P)**, changes in the composition of goods in final demand **(YH)** and changes in trading partners the final goods are sourced from **(YT)**, and allows to analyse whether changes in impacts are occurring because of changes in the volume or the composition of final demand. **P** is given in EXIOBASE 3, collected from the World Bank (Simas, Stadler, et al., 2018), and **y** is found by dividing country-level consumption by population. **YH** is found by collapsing the final demand matrix over the countries, giving a matrix showing how much each country demands of each of the 200 products, irrespective of where these are produced. **YT** is found by dividing the final demand matrix by **YH** so we can see what share of each consumed product is sourced from what region. For GHG emissions, also the changes in direct household emissions, $\mathbf{F_{hh}}$, are included in the analysis, while this is not a relevant determinant for employment. The final demand for exports from the BRIICS countries to the rest of the world is split into the effect of changes in the total volume of exports ($\mathbf{Y_{volume}}$), and the composition of each country's exports ($\mathbf{Y_{comp}}$). $\mathbf{Y_{volume}}$ is found by summing the total monetary exports from each country, irrespective of what goods they are exporting. $\mathbf{Y_{comp}}$ is found by dividing each country's exported products by the volume of exports, so it reflects the share of each product in each exporter's total exports.

4. Results

4.1. Development of employment and emissions over time

a) **b)**

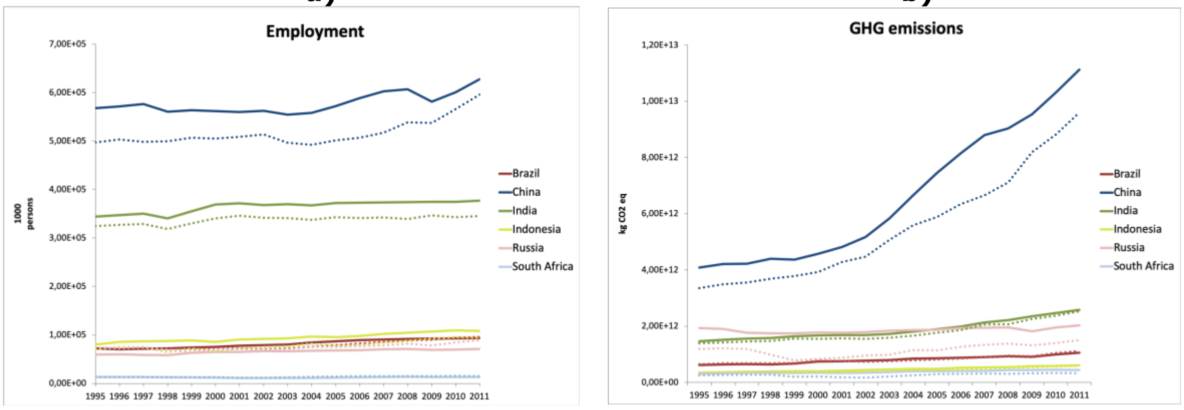


Figure 5 - Development of employment (a) and GHG emissions (b) in the BRIICS countries' production and consumption from 1995 to 2011. Production solid lines, consumption dotted lines

The employment and GHG emissions in the BRIICS countries' consumption and production from 1995 to 2011 are displayed in Figure 5. China and India with their large populations employ the most workers, and they also have the largest GHG emissions in both production and consumption, together with Russia. While China's emissions in both production and consumption were much higher than in all the other countries in the group, India's emission levels are more similar to the other countries. In all the BRIICS countries, employment and emissions are much higher in the domestic production than in imports and exports (Figure B 1 and Figure B 2) while the largest growth in impacts between 1995 and 2011 has been in their imports and exports (Table B 1). The high growth rates in imports as well as exports compared to the domestic economy illustrate the growing importance of international trade for satisfying demand and generating impacts across countries. In most cases, growth in impacts was higher in imports than in exports, which underlines that the emerging economies are becoming important global consumers driving impacts in other countries. Generally, growth in emissions has been larger than the growth in employment, implying that the growing emission intensities of jobs in the BRIICS are occurring because emissions are continuing to grow while the amount of jobs is stabilizing.

4.2. Characteristics of consumption

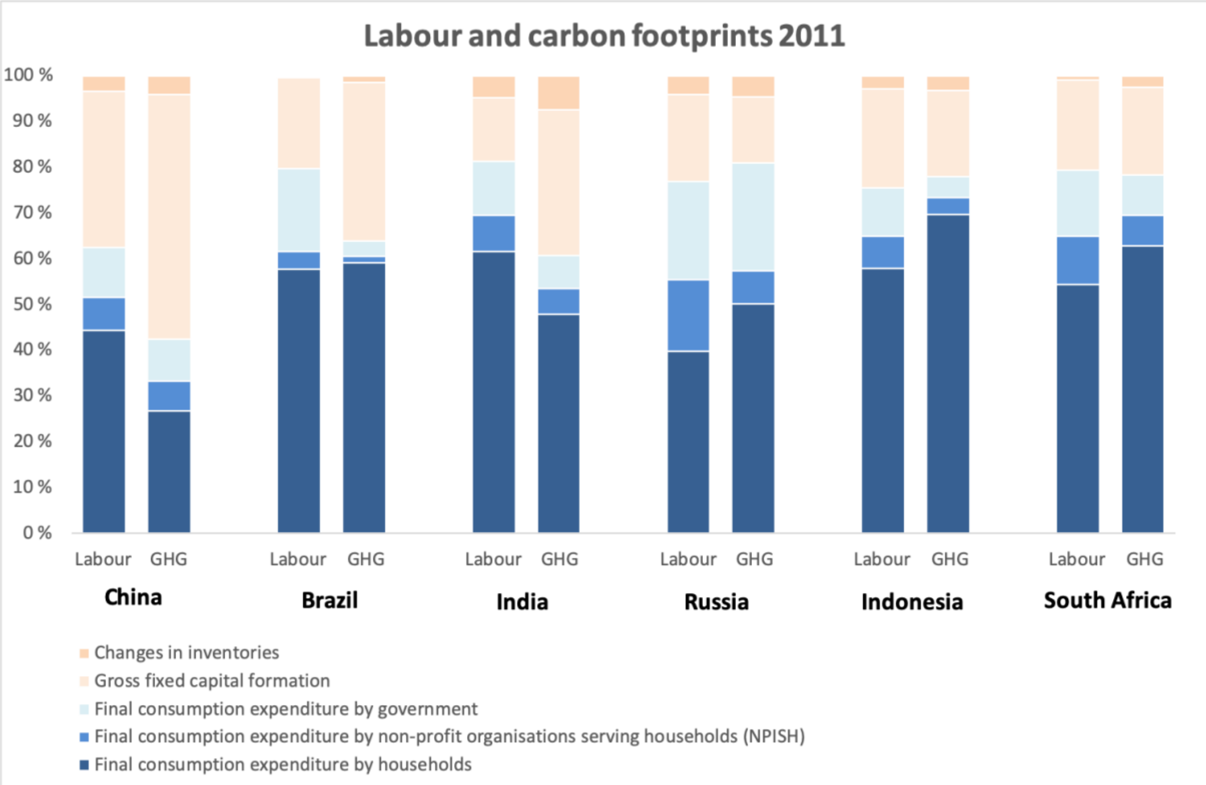


Figure 6 - Distribution of the labour and carbon footprints on consumer categories, 2011

Figure 6 shows how different consumption categories contributed to the BRIICS' labour and carbon footprints in 2011, illustrating the importance of different consumers in generating the two footprints. Figure B 3 displays the 1995 distribution for comparison. The category "final consumption expenditure by households" includes direct household spending while the category "final consumption expenditure by non-profit organizations serving households (NPISH)" includes the expenditure of private, non-market producers like for example churches or sports clubs, and both categories are usually attributed to household consumption (Eurostat, 2017). In all the countries, household consumption was the most important consumption category contributing to the employment footprint in both 1995 and 2011. It was also the most important consumption category for the carbon footprints, except in China where capital formation was responsible for more than 40% of the footprint in 1995 and more than half in 2011. The share of household consumption's contribution to both footprints was reduced over time in all the countries, except Indonesia where changes over time were small. Gross fixed capital formation and government spending became more important at the expense of household consumption, illustrating the growing importance of investments for generating supply chain impacts, typically found in studies of emerging countries (Chen et al., 2018; Peters et al., 2007), and the investments are contributing more to emissions than to employment. Comparing to the distribution of the footprints of EU28 and USA (Figure B 4) also there households were the most important drivers of employment and emissions, but while there are clear changes in the composition of the footprints since 1995 in most of the BRIICS countries, the shares in the EU28 and USA were stable over the same period, illustrating that the BRIICS are currently undergoing important economic changes with consequences for their footprints, while the developed countries are more stable.

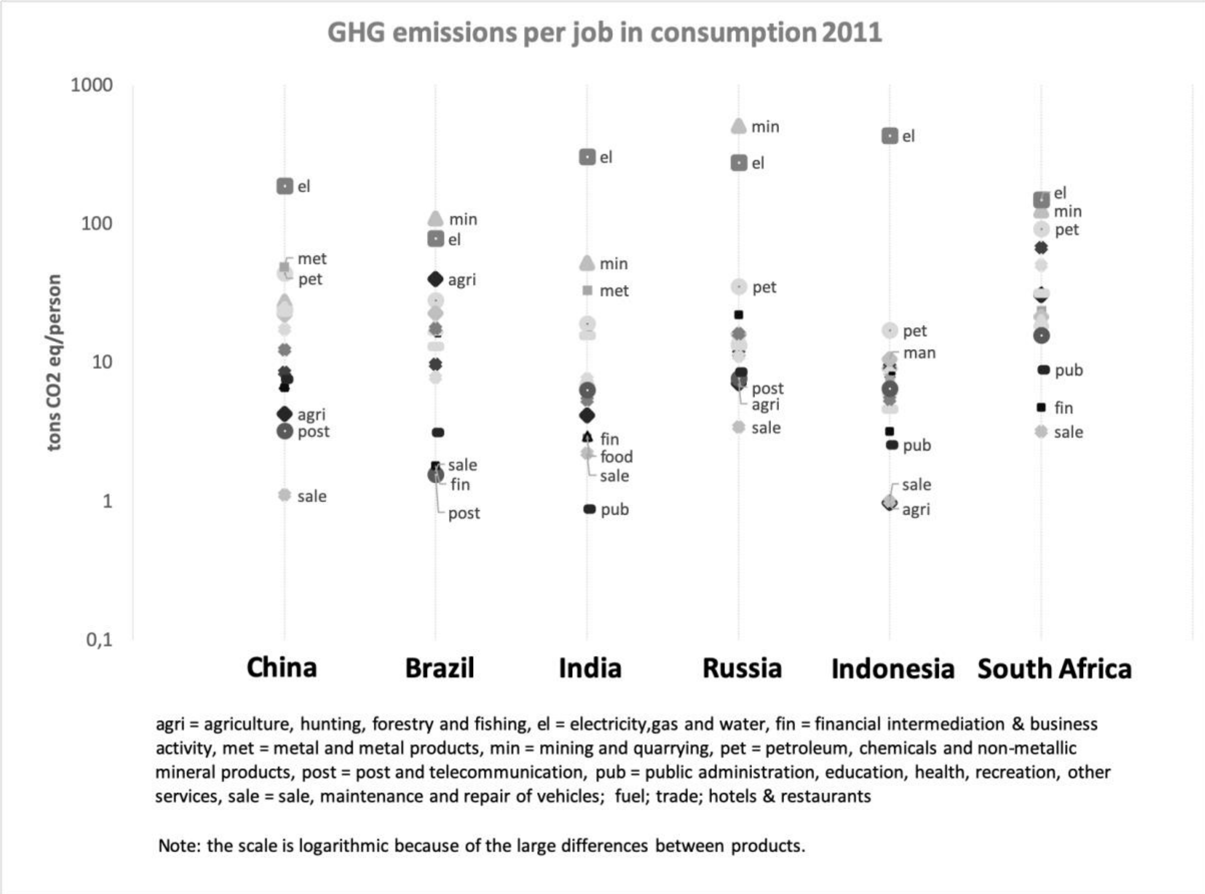


Figure 7 - GHG intensities of jobs by consumption goods, measured by tons of CO_2-equivalents per person-year-equivalent in the supply chains producing these goods.

By goods, consumption of services is important for generating employment throughout the supply chain in all the BRIICS countries, especially in Brazil, Russia and South Africa where the consumption of services is generating more than half the labour footprint (Figure B 5). Consumption of services has relatively less emissions per job compared to other sectors, because a lot of people are employed in services and there are fewer direct emissions. Still, they are important also for GHG emissions, because the consumption of services is generating emissions in other sectors through their supply chains. Which services have the lowest GHG intensities per job varies somewhat across countries, but "sale, maintenance and repair of vehicles; fuel; trade; hotels and restaurants" is among the services with the lowest emissions per job created in all the BRIICS countries, along with post and telecommunication, financial intermediation and business activity, and public administration (Figure 7).

In India and Indonesia, the consumption of primary goods, like agricultural products and food products, are the most important in generating employment (Figure B 5). The importance of these sectors is related to the lower income-levels in these two countries compared to the rest of the group, as it is common to spend larger shares of incomes on food when incomes are low (Hertwich & Peters, 2009). In addition, the agricultural sectors are very labour-intensive in these countries. Primary sectors are also important for the emissions in these two countries, but in this case mining and quarrying is most important. This means that food and agricultural goods are among the goods with the lowest emission intensities of jobs, while mining is among the products with the highest intensities of jobs in India and Indonesia (Figure 7). In Brazil, the consumption of primary goods causes less than 20% of the employment, while causing more than 40% of the GHG emissions, making agriculture and mining two of the sectors with the highest emission intensities of jobs in Brazil (Figure 7 and Figure B 5). In China and Russia agriculture is also among the sectors with the lowest intensities of jobs, while mining is among the high-intensity goods in Russia and South Africa, but the shares of primary goods in the total footprints are lower in these countries compared to India, Indonesia and Brazil.

Consumption of secondary products are the most important in generating GHG emissions for all the countries except Brazil. Construction is important for generating both emissions and employment in all the BRIICS countries, and especially China (Figure B 5). This means that construction has relatively low emission intensities of jobs compared to other secondary products, but still cause significant amounts of emissions. The share of construction in the GHG footprint grew from 1995 to 2011 in all countries but Russia, mainly at the expense of primary goods. Also consumption of electrical and machinery and other secondary goods became more important over time for the GHG footprint in most of the BRIICS (Figure B 6). A product category that stands out as very important for generating emissions but not employment is electricity, gas and water, in all except Brazil, where the consumption of this sector is not very important for emissions because of their large share of hydropower. The consumption of electricity, gas and water is creating the most emissions for each job created in most of the countries, except in Russia and Brazil where consumption of mining and quarrying have slightly higher GHG intensities of jobs. Growth in capital formation has been important for the GHG emissions in the BRIICS consumption, and the large shares of emissions related to consumption of construction, electricity and other secondary goods can be related to the growing capital formation and investments in infrastructure. Changes in consumer habits towards more carbon-intensive goods following growth in incomes can also be part of the explanation (Hertwich & Peters, 2009).

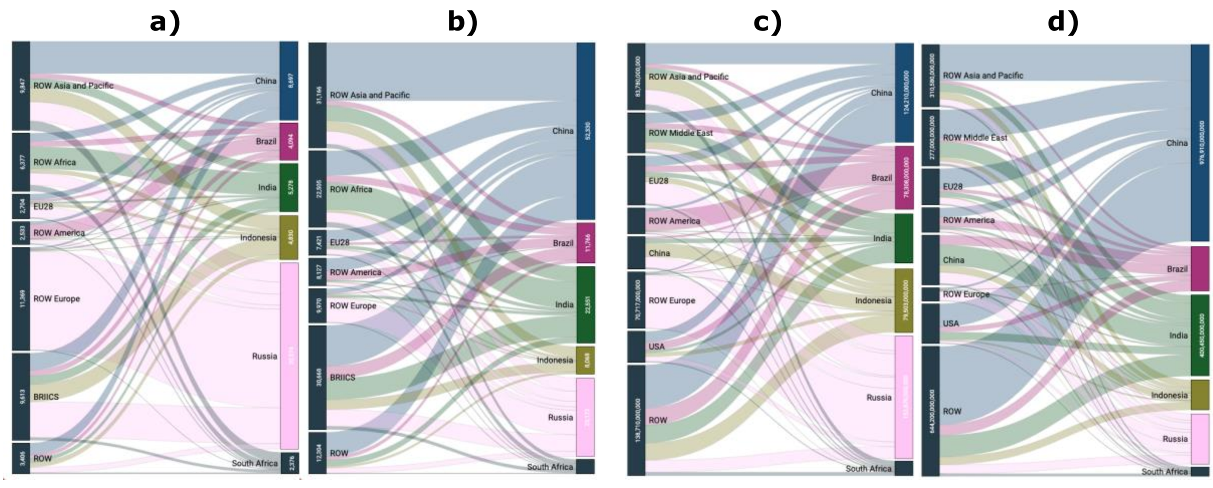


Figure 8 – Sources of imports of employment into the BRIICS countries in 1995 (a) and 2011 (b) (units: 1000 person-year-equivalents), imports of GHG emissions 1995 (c) and imports of GHG emissions 2011 (d) (units kg CO_2-equivalents). (Colours of the flows: Blue: China, Magenta: Brazil, Green: India, Yellow: Indonesia, Pink: Russia, Grey: South Africa).

The impacts in imports of the BRIICS have been increasing fast between 1995 and 2011, and as Figure 8 displays, the source countries of imported employment and emissions have also changed during the period. For the employment imports in 1995 there is a pattern of the BRIICS countries importing labour from geographically close regions. For example is ROW Europe the most important source for Russian imports while ROW Asia and Pacific is the most important source for China and ROW America for Brazil. Also, generally the regions with relatively cheap labour like ROW Asia and Pacific and ROW Africa were important sources of employment for the BRIICS countries. The same patterns are not seen as clearly for GHG emissions, where imports from more developed regions like the EU28 and USA as well as the energy-intensive Middle East were relatively more important than for labour. Several of the BRIICS were importing relatively large shares of employment and emissions from China as well already in 1995, and by 2011 especially the share of carbon imports from China to the other BRIICS countries grew. Russia was the biggest importer of labour and emissions among the BRIICS in 1995, while in 2011, China had become the largest importer of both labour and GHG emissions as well as being an important exporter. In 2011 China was the largest source country of GHG emissions in imports to Brazil, India and Russia, and also second most important for Indonesia and third for South Africa. China is becoming a very important actor in the international trade of emissions and employment. Over the period, India became the second largest importer of emissions, passing Russia and Brazil, which shows that this country is also becoming a very important global driver of emissions through their imports. The importance of China and India relative to the rest of the BRIICS can be related to their large populations, but also that they have experienced exceptional growth after liberalizing their trade policies since the 1990s.

4.3. Characteristics of exports

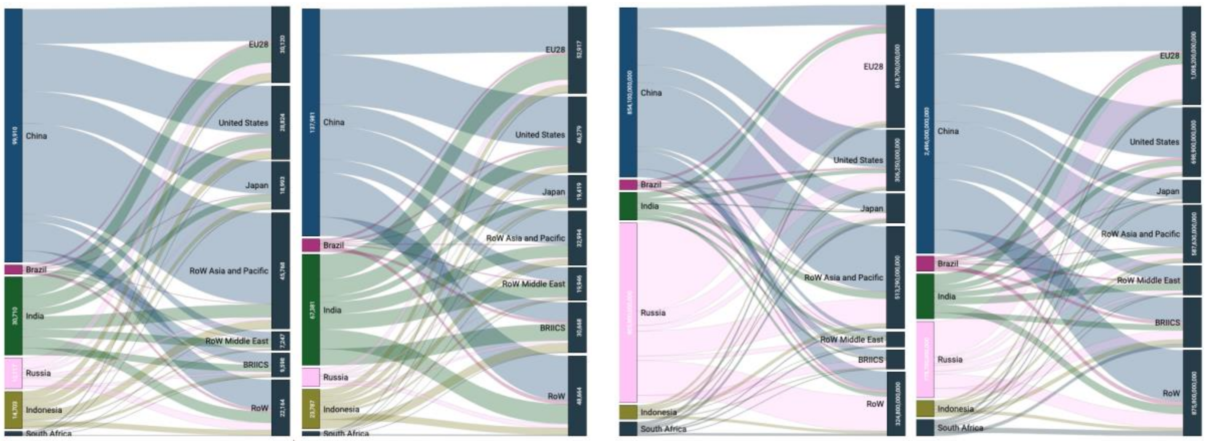


Figure 9 - Exports of employment from the BRIICS to consumer regions 1995 (a) and 2011 (b) (unit: 1000 person-year-equivalents). Exports of GHG emissions from the BRIICS to consumer regions 1995 (c) and 2011 (d) (unit: kg CO_2-equvalents). (Colours of the flows: Blue: China, Magenta: Brazil, Green: India, Yellow: Indonesia, Pink: Russia, Grey: South Africa).

Also the patterns of exports shifted between 1995 and 2011. China was the largest exporter of employment among the BRIICS in 1995, but in 2011, the share of India had grown larger, especially at the expense of China. India is a labour-intensive economy with a large share of exports in agriculture and services which can explain why their exports of labour have increased fast after trade liberalization. Further, China has increasingly exported less labour-intensive products, specializing in more sophisticated manufactured exports, which can explain their decreasing share in exports of labour and large role in emissions embodied in exports. Russia was the largest exporter of emissions in 1995 followed by China, but in 2011 China, India and Indonesia all exported more emissions than Russia, and Russia’s share of labour exports also decreased. ROW Asia and Pacific was the most important region for the BRIICS' exports employment in 1995, especially for China, but by 2011 other regions, including the EU28 and USA, became relatively more important importers of employment from the BRIICS countries. ROW Asia and Pacific was also an important region importing GHG emissions from the BRIICS, along with the EU28 in 1995. While the European countries imported most of their emissions from Russia, the Asian region imported most of their emissions from China. By 2011 ROW Asia and Pacific had become a much less important importer of emissions from the BRIICS as well, at the expense of EU28, USA and the BRIICS themselves. The changing patterns reflect the outsourcing of labour- and emission-intensive production from the developed countries to emerging countries. There is also a growing importance of the BRIICS countries as importers of employment and emissions from each other, which is in line with the BRIICS contributing to growth in south-south and intra-BRIICS (Meng et al., 2018; Singh & Dube, 2014).

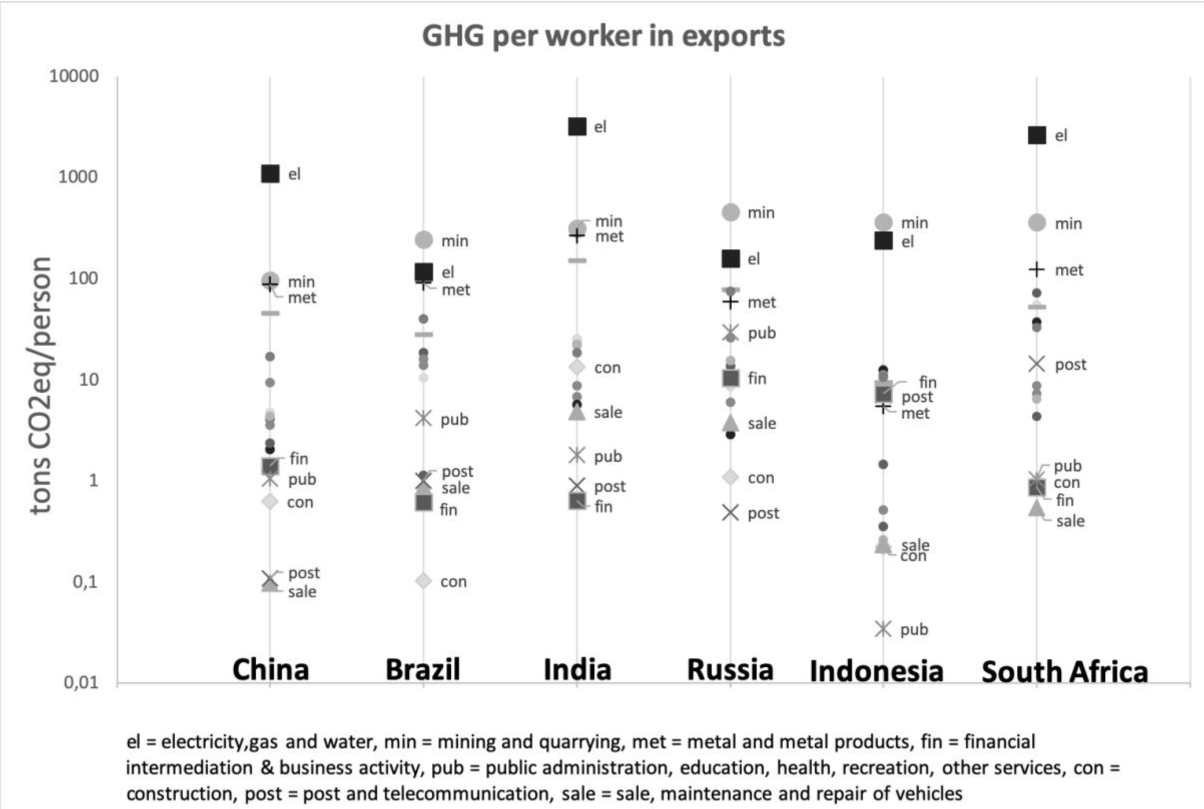


Figure 10 – Greenhouse gas intensities of jobs in the production of exported goods. Unit: tons CO_2 equivalents per person-year-equivalent. Note that the scale is logarithmic because of the large differences between sectors.

By products, the largest amount of emissions generated for each job embodied in exports is in the production of electricity, gas and water in China, India and South Africa, and in mining and quarrying in Brazil, Russia and Indonesia (Figure 10). These patterns are similar to what was found for the intensities of consumption goods. However, for the products with the highest emission intensities, the intensities are higher in exports than in the consumption, while for low-intensity sectors, the intensities are even lower in exports. This is because the consumption approach covers the full supply chains, while the exports only reflect the emissions and labour within the specific production of these goods. This means that the consumption approach includes the more labour-intensive inputs required upstream for producing for example electricity, and the more emission-intensive inputs required upstream for producing for example services, so the intensities converge when considering the full supply chains.

The production of electricity, gas and water for exports are generally contributing to low shares of the value added in exports, while mining and quarrying are contributing to important shares of the value added, especially in Russia, South Africa, Indonesia and Brazil (Figure B 8), reflecting the importance of exports of mined products like oil, gas, coal and other minerals in these countries. Production of services as well as construction for exports is creating the lowest amounts of emissions for each job created, as these are sectors with high labour-intensity and low direct emissions. Further, the production of sectors with low emissions per job are also contributing significantly to the generation of value added in exports (Figure B 8). Figure B 7 shows that production of services for exports is already a very important employer for most of the countries, especially in South Africa where 60% of the export employment is in services. In all the countries the share of labour employed in exports of services relative to other goods increased from 1995 to 2011. The largest shares of emissions on the other hand, in most of the countries and especially China, are from manufacturing.

4.4. Drivers of emissions and employment footprints

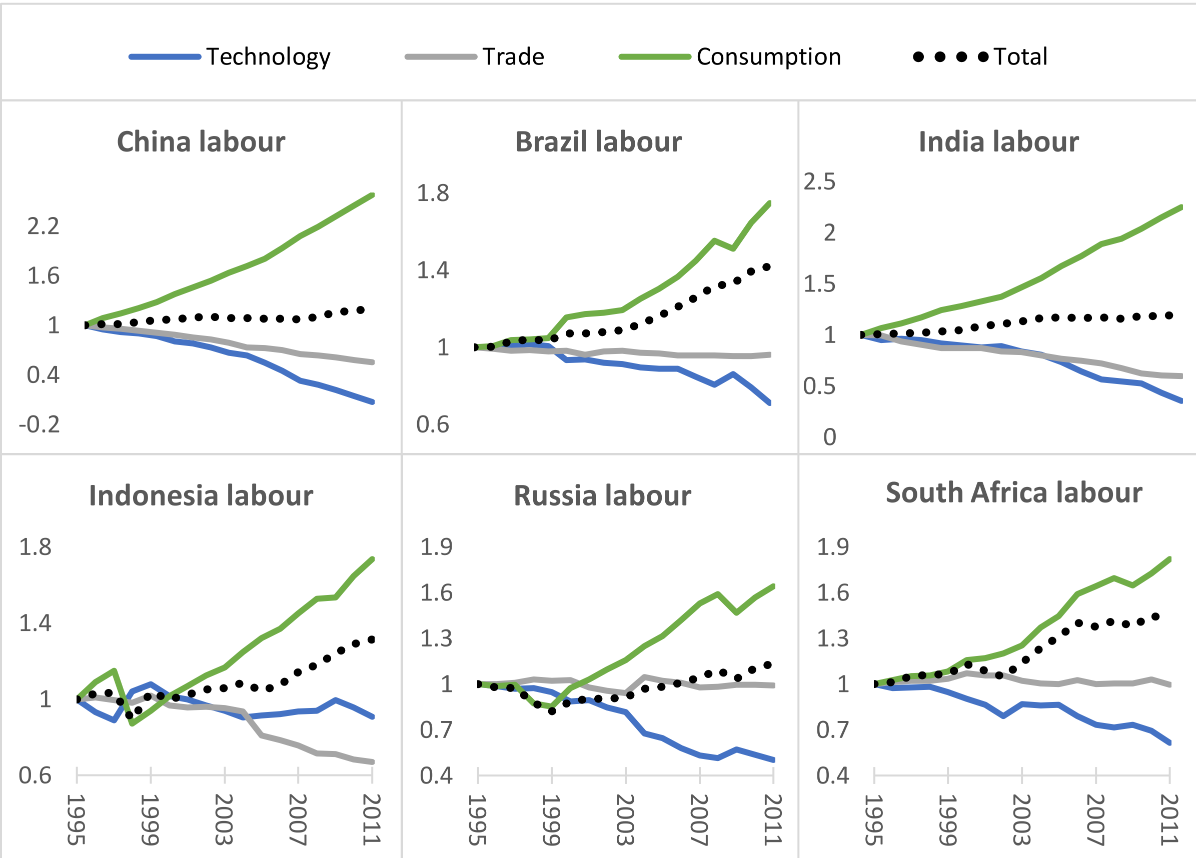


Figure 11 – Cumulative contributions of drivers of employment in the BRIICS' consumption from 1995 to 2011. Note that the scales are different for each country (unit: change relative to the 1995 employment level).

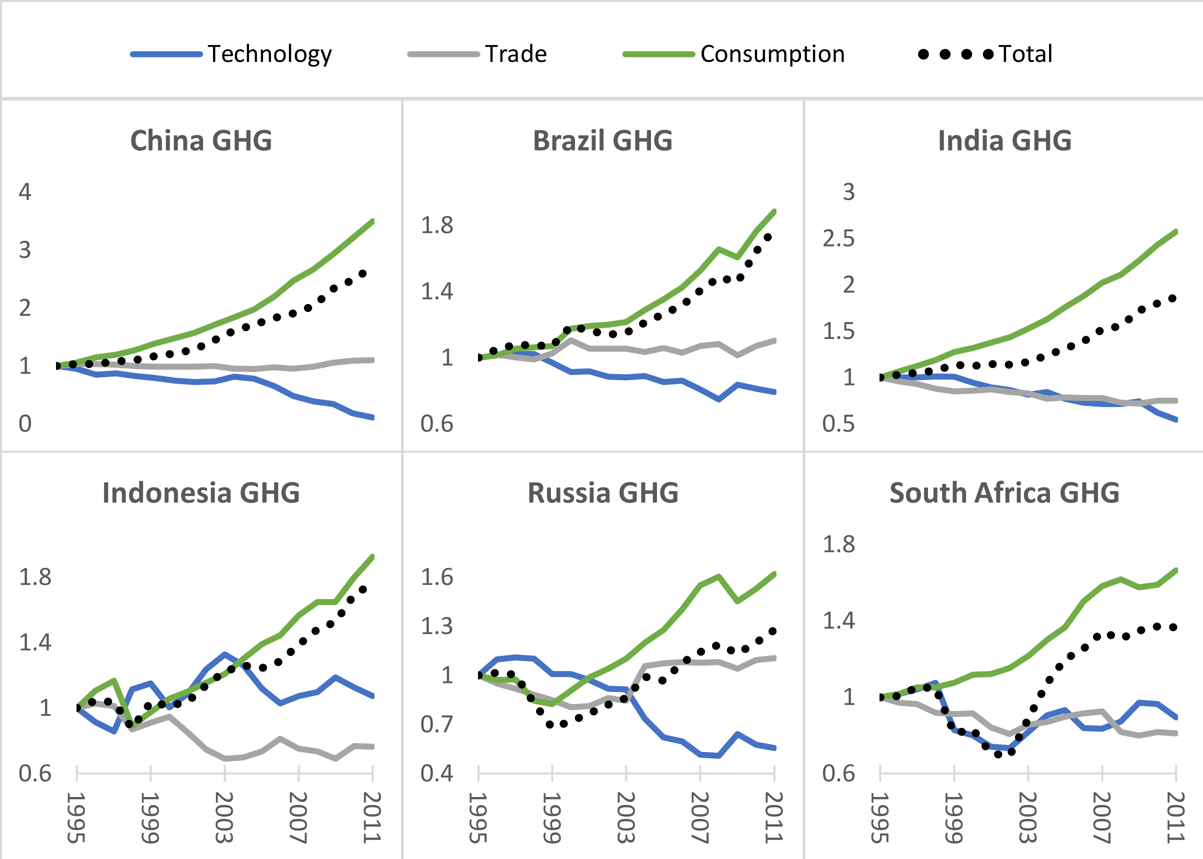


Figure 12 – Cumulative contributions of drivers of GHG emissions in the BRIICS' consumption 1995-2011. Note that the scales are different for each country (unit: change relative to the 1995 emission level).

The cumulative effect of technology, trade and consumption on employment and emission footprints of the BRIICS are displayed in Figure 11 and Figure 12 and more detailed results disaggregated for the eight drivers described in Table 3-1 are presented in Figure B 9 and Figure B 10. The values for each driver are the cumulative changes over the time series relative to the 1995 impact level, to be able to compare the contributions of drivers to emissions change and employment change. In some cases, the cumulative effects of technology changes in 2011 has negative values, which does not mean that emissions in 2011 would have been negative due to the isolated effect of technology improvements, but that the cumulative gains over the time series has been higher than the total emissions in 1995 because the total emissions have been growing fast over the time series, and therefore also the cumulative gains over time become large. Between 1995 and 2011 the labour footprints of India, China and Russia increased by a factor of around 1.2 and around 1.4 in Brazil, Indonesia and South Africa. In Russia most of the growth happened after 2003, while the labour footprint was decreasing before that. Indonesia experienced a drop in the labour footprint around 1997, while the fastest growth happened after 2005. The changes in GHG emissions in Russia's consumption were very similar to the patterns for labour in consumption, with reductions in the beginning of the time series, but growth eventually, by around a factor of 1.2 by 2011 compared with 1995 (Figure 12). In the other BRIICS countries however, GHG emissions in consumption were growing faster than labour, most clearly in China where emissions increased by a factor of 2.7. In India, Brazil and Indonesia emissions grew by a factor of about 1.8, while growth in South Africa was slightly slower growing 1.3 times over the period. In South Africa and Indonesia there were also reductions in the emissions to begin with before starting to grow, while in the other three countries emissions were growing throughout the period.

In China, India and Indonesia changes in trade relationships had a strong negative effect on employment footprints with around 45% cumulative reduction in China relative to the 1995 level, and around 30% reduction in India and Indonesia, which means that these countries over time bought their consumption goods from trading partners with lower labour-intensities. For Brazil, South Africa and Russia on the other hand, changes in trading relations had a very small effect on the labour footprint over the time period. In India, Indonesia and South Africa the changes in trading relations were important for reducing the emissions in their consumption, and the cumulative gains were around 20% of the 1995 emissions in each of them, while in Russia, Brazil and China changes in international trade contributed to a 10% growth in carbon emissions. The trade driver includes the effects of changes in trading partners for intermediates in the production of the BRIICS consumption goods, and changes in trading partners for the BRIICS' final consumption goods. In most cases, the changes in trading partners for intermediates used in the supply chains had a very small effect on both emissions and employment, while the international trade effects were mainly due to shifts in trading partners for final goods (Figure B 9 and Figure B 10).

For all the BRIICS countries, the most important driver of growth in employment and carbon footprints was growth in consumption, more than doubling the employment footprints of India and China and contributing to around 70% growth in the other countries, and the effect was even stronger for GHG emissions in most cases. Consumption includes the effect of changes in consumption level per capita, composition of final consumption goods and population. In the case of GHG emissions, the consumption driver also includes effects of direct household emissions of GHGs, but for all the countries changes in this driver had relatively little effect on total emissions compared to the other drivers. The most important effect was increased consumption level per capita, reflecting the large economic growth in these countries since the 1990s (Figure B 9 and Figure B 10). This driver to a large extent mirrors changes in GDP per capita as seen Figure 2, and is closely linked to important economic events in the countries. For example it can be seen that it had a reducing effect on employment and emissions in Russia and Indonesia in the beginning of the period because of these countries' respective economic challenges in the 1990s, and that the consumption impacts of Brazil, Russia, Indonesia and South Africa were affected by the global financial crisis in 2009. Also population growth was an important contributor to growth in employment and emissions in most of the countries, but at various extent, reflecting the differences in population growth rates seen in Figure 2. In Russia however, population has been declining throughout the period, and had a reducing effect on the total consumption volume and hence both impacts. In all the countries, changes in the composition of consumption had a very small effect on the demand for labour, reflecting that the volume of consumption has been much more important than what sort of goods are being consumed.

In all countries but Indonesia, the strongest driver of reduction in both footprints has been changes in technology. The technology driver includes the effect of changes in the labour or carbon intensity of each sector, and the effect of changes in input structures of sectors. More productive use of labour and lower emissions per unit of output (S in Figure B 9 and Figure B 10) have contributed to keeping employment footprints quite stable despite economic growth but were far from enough to offset the large growth in carbon footprints. In Russia and South Africa carbon intensity increased and contributed to growth in emissions in the beginning of the period, which could be related to the economic downturn and inefficient use of resources after the collapse of the Soviet Union and abolishment of apartheid. However, by the end of the period, the carbon intensity of South Africa decreased significantly, and contributed to significant emissions reductions relative to 1995. In China, India and Brazil technology improved throughout the period, most strongly in China for emissions. The effect of labour productivity improvements was strongest in India's consumption, where it isolated reduced the employment footprint by 70%. In Indonesia on the other hand, the labour productivity effect was significantly lower than in the other countries, contributing only to a 15% reduction in the employment footprint. However, the effect was fluctuating over time, so the use of labour per unit of production increased in periods of lower consumption, keeping the employment relatively stable. For most of the countries it is seen that in periods with lower consumption, labour and carbon intensities increase, while the intensities decrease with growth in consumption. This is similar to the results found for the production in the industrial sector in selected EU countries by Kopidou et al. (2016). The results reflect an inertia of production, where reduced consumption does not immediately reduce production, which means that there may still be emissions, and jobs will not be immediately lost.

Changes in input structures of production was contributing to slight growth in employment in the consumption of most of the BRIICS, except Russia and Indonesia, so while the supply chains were generally becoming more efficient in the use of labour in each sector, the production of their consumption goods used larger shares of labour-intensive inputs. This could reflect the growing importance of services in consumption and supply chains, that are labour-intensive, but more productive than for example agriculture. However, the input structures also shifted towards more use of carbon-intensive intermediates, which had a very strong effect on growth in carbon footprints of China, South Africa and Indonesia and reflects the industrialization of these countries (Simas, Hertwich, et al., 2018). In Russia, and to some extent in India, changes in the input-structures shifted towards the use of less carbon-intensive inputs. For India this could be related to the growing importance of services, while in Russia most of the change happened before 1999, and similar results were found in Malik and Lan (2016) and reflect the major restructuring and efficiency improvements of the Russian economy after the fall of the Soviet Union.

4.5. Drivers of emissions and employment in exports

Figure 13 shows the changes in employment in the BRIICS countries to produce exports, to both intermediate and final use in other countries, and Figure 14 shows the changes in exports of emissions. More detailed results are displayed in Figure B 11 and Figure B 12. These only account for changes occurring in the production stages within these countries' borders before being exported abroad, so they do not include impacts occurring in upstream suppliers abroad, and includes all impacts embodied in products exported abroad, whether used for final consumption or as intermediate inputs in production abroad. The largest growth in exports employment between 1995 and 2011 was in India and Brazil, where it doubled over the period. China had quite stable employment and emissions in exports until 2001, around the time they joined the WTO, when it started growing, employment reaching a peak around 1.5 times the 1995 level in 2007 and emissions tripling at the same time. Also in Brazil, India and Indonesia emissions embodied in exports tripled over the period. Russia's exports employment was decreasing until 1997, then growing fast from around 1998 to 2000 where it reached 1.5 times the 1995 employment. Since then the employment in exports decreased slightly again, and also the GHG emissions in Russia's exports decreased since 2000. In South Africa and Indonesia the employment in exports grew by around 60% between 1995 and 2011, although fluctuating over time, and South Africa's emissions doubled.

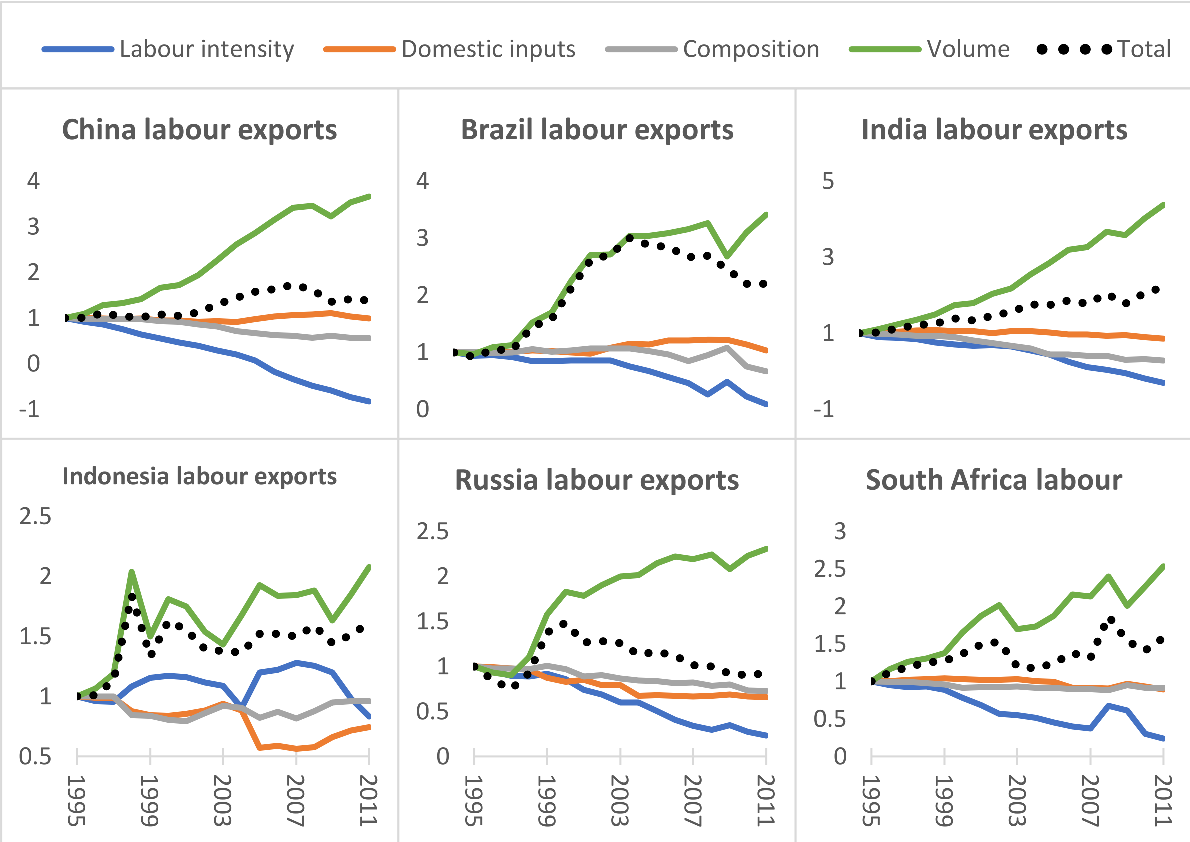


Figure 13 - Drivers of employment in exports 1995-2011. Note that the scales are different for each country (unit: change relative to the 1995 employment in exports).

The increased volume in the demand for exports is the most important driver of employment and emissions in exports in all the BRIICS countries, most strongly in India. In all the BRIICS, the growing volume of exports has contributed more to growth in emissions than employment, highlighting that the exported products are relatively more carbon- than labour-intensive. In 2009 there is a clear drop in the demand for exports from all of the BRIICS, which shows that the exports employment as well as emissions in all of these countries' exports were affected by lower demand during the global financial crisis. Still, the demand soon increased again in all of these countries, so there was no long-term impact on the employment nor emissions in exports, which could be linked to the growing importance of South-South trade relative to trade with developed countries (Meng et al., 2018). Throughout the period, the demand for exports from South Africa and Indonesia is more fluctuating than in the other countries and contributing to the fluctuations in the exported employment and emissions.

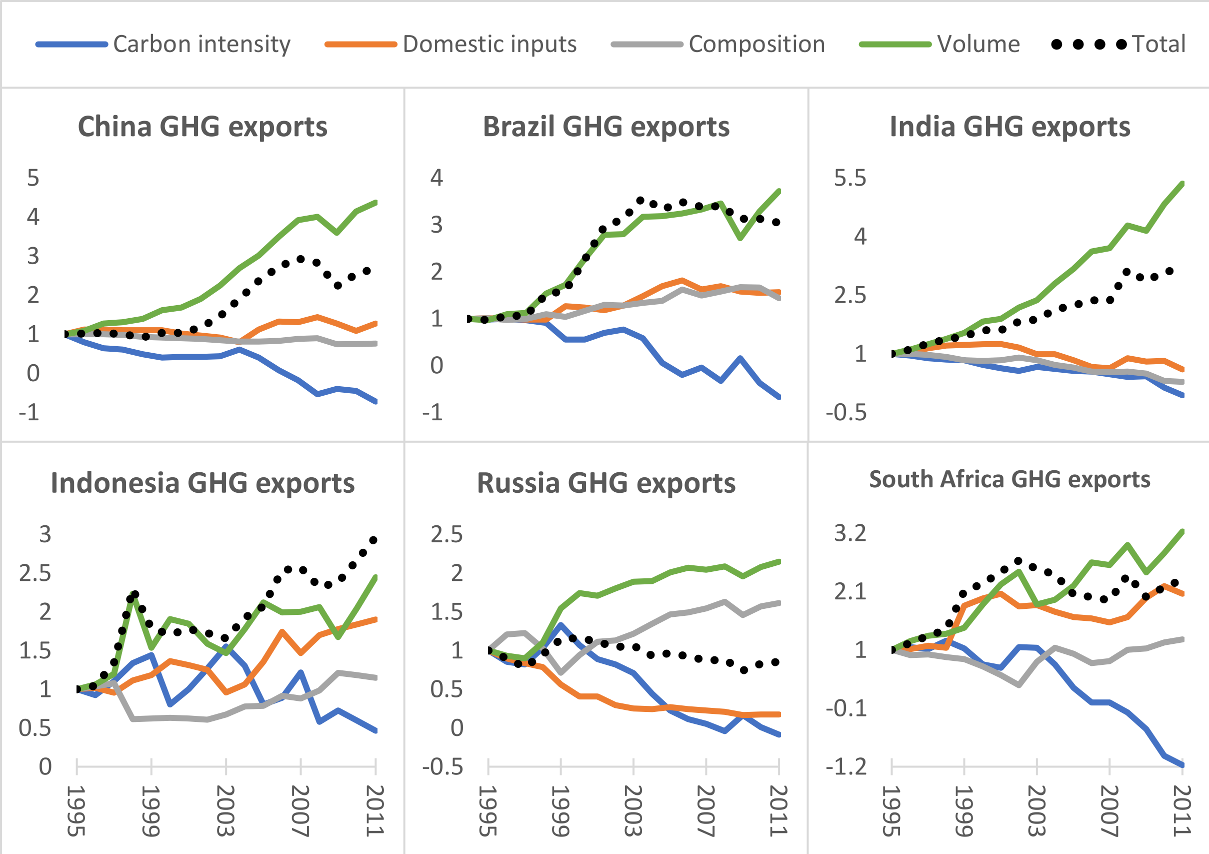


Figure 14 – Drivers of GHG emissions in exports of the BRIICS countries from 1995-2011. Note that the scales are different for each country (unit: change relative to the 1995 emissions in exports).

The change in the composition of exports had a negative effect on employment in exports in all the countries except Indonesia, meaning they over time exported less labour-intensive products. The composition of exports was an important driver of emissions in exports in Russia and Brazil, contributing by a factor of around 1.5 to the growth in emissions while this driver had a very small, slightly negative effect on employment in exports in these countries. In South Africa and Indonesia the composition of exports had various effects on GHG emissions in exports over time, contributing to significant reductions in emissions in the beginning of the time series, but eventually contributing to growth, ending up at a factor of around 1.2 in 2011 compared to 1995. This means that these four countries exported more carbon-intensive, and to some extent less labour-intensive goods over time, which is related to the importance of oil, gas, coal and other minerals in their exports. For China and India the composition of exports demand contributed to offsetting the GHG emissions in exports, meaning that they were exporting less carbon-intensive products. Still, the volume of exports increased so much that the total effect on emissions was still positive in all the BRIICS countries. M. Xu et al. (2011) found the composition of exports to be most important for China's emissions, while Pan et al. (2017) found volume to be most important. My results are thus more in line with the findings of Pan et al. (2017). Also for the other countries it is clear that the volume of exports is more important than the composition, and Y. Xu and Dietzenbacher (2014) emphasized the importance of export volumes for emissions in trade. The differences between these analyses and M. Xu et al. (2011) could be related to the slightly different time series covered, but also suggest that the results of this analysis is correct and that the results of M. Xu et al. (2011) are based on more uncertain data.

The growth in emissions in exports has been slowed by improvements in the emission intensity of production in all the countries. The strongest effect of carbon intensity improvements on emission reductions was in South Africa, and most of the improvements happened since the beginning of the 2000s. In Russia, changes in the emissions per unit of output contributed to growing emissions in exports to begin with, but from the 2000s, the improvements in this driver, as well as the changes in the domestic input structure of production towards less carbon-intensive inputs were large enough to completely offset the growth emissions from growing export volumes and composition. There was also a very strong decrease in the emissions per unit of output especially in China and Brazil. The changes in domestic input structure of production contributed to growth in emissions in exports in China by 30%, in Brazil by 50% and especially in South Africa and Indonesia where it contributed to a doubling of exports emissions, meaning that these countries increasingly used inputs in production with higher carbon intensity. In the beginning of the period the changes in input structure also contributed to growth in emissions in India's exports, but by 2011 it had contributed to a 40% reduction in emissions in exports compared to 1995.

The labour intensity of production is also decreasing in all these countries, contributing to slowing the growth in labour in exports, meaning that the labour employed in all the BRIICS' exports production is becoming more productive. This effect is strongest for China, but significant for all the BRIICS. In Indonesia the labour used per unit of production was increasing strongly from 1997 to 2000 and from 2004 to 2007 before decreasing again, contributing to around a 20% reduction in exports employment in 2011 compared to 1995, reflecting that the labour was less productive in times of lower demand, which suggest that with lower consumption of exported goods, the workers were not immediately laid off. At the same time this effect is offset by changes in the domestic input structure of Indonesia, using less labour-intensive inputs in production, so the total effect of technology changes on exports employment is not large. Changes in the input structure of production had a very small impact on the amount of labour in exports in all the other countries. For most of the countries the effect became negative in the end of the period, meaning that they are starting to use slightly less labour-intensive inputs in their exports production.

5. Discussion

5.1. Decoupling consumption and emissions

The BRIICS countries liberalized their trade policies and became more integrated with the world market in the 1980s and 90s. This allowed them to become important exporters of products to the rest of the world, which has provided economic growth and employment opportunities, and allowed them to become important global consumers with larger access to consumption goods and higher standards of living. However, this also contributed to growth in emissions in their exports and in their consumption, and emissions have been growing fast while employment levels have been more stable over time. This has contributed to growing emission intensities of jobs, which are now catching up with the intensities of jobs in developed countries, even though development and income levels are still significantly lower in the BRIICS than in developed countries (Berg, 2018).

The strong effect of consumption growth driving emissions and lower contribution to job growth suggests that measures to reduce the volume of consumption could be very efficient for reducing emission intensities of jobs. However, consumption growth is necessary for the emerging countries to continue developing and gaining higher incomes, more employment opportunities and higher standards of living (Hubacek, Guan, & Barua, 2007). Arto and Dietzenbacher (2014) do not expect that policies aiming at reducing emissions would be possible to implement in developed countries, which makes it even less relevant in the countries that are still undergoing development and have significantly lower consumption levels per capita. Thus, it can be expected that the volume of consumption will, and should, continue growing in the BRIICS in the future, and it is more important for green job creation to focus on decoupling the consumption growth, job creation and human development from growth in emissions, through changes in consumption patterns or production technologies.

5.1.1. Changing consumer behaviour

From 1995 to 2011 the carbon and employment footprints of the BRIICS countries shifted from a high importance of household consumption towards a larger share of capital investments. The investments are occurring in carbon-intensive sectors like construction and other secondary products, which means that they are contributing to larger shares of the carbon footprints than labour footprints. Especially for China this change is very pronounced, which is linked to the fast growth in China's economy and shifts in the economy from labour-intensive production to more heavy industries and building up infrastructure related to that. In India and Indonesia, countries with lower income-levels, consumption of agricultural and food products are more important for generating footprints than in the other countries, and especially in Indonesia the distribution of footprints did not change as much towards capital investments as in the other countries yet. With continued growth in incomes it is likely that also these countries transition to a higher importance of capital investments and carbon-intensive secondary products which could significantly increase carbon intensities of jobs, unless these patterns are targeted for improvements. However, also the consumption of services is becoming more important in the BRIICS countries, contributing to generating important, high-productive employment, while not contributing significantly to carbon footprints. The investments in capital are likely to be temporary (Minx et al., 2011), which together with the growing importance of consuming services implies that there are potentials for carbon footprints to be lower in the future, when main investments in infrastructure are done.

The analysis of drivers shows that the historical changes in consumption patterns have not had a significant impact on job creation or emissions in the BRIICS relative to other factors, but the year-by-year changes in consumption patterns towards more carbon-intensive consumption could still have contributed to accelerating the effect of growing consumption volumes. Also, there could be potentials for these changes to have a greater effect in the future as the countries are still in transition and may experience much larger changes in their consumption patterns in the future. There may also be potentials to develop infrastructures, appliances and consumer habits in less wasteful ways rather than following the development patterns of developed countries (Hubacek et al., 2007), and consumption habits may shift towards higher quality goods with growing incomes, which could contribute to decoupling consumption growth from emission growth if these last longer than low-quality products, and are produced with less carbon-intensive technologies (Girod & De Haan, 2010). Patterns from developed countries also show that growth in emissions and energy use is not necessary for continued development, as human development has become decoupled from these impacts over time (Steinberger & Roberts, 2010; Tukker et al., 2016). This suggests that continued shifts in the BRIICS' consumption patterns towards more energy- and carbon-intensive goods, as currently seen, may not by necessary for continued development.

Changing consumer habits have been identified as important for mitigating climate change (Girod, van Vuuren, & Hertwich, 2014). In this analysis products were sorted by their emissions intensities of jobs created in their supply chains, and shifts in consumption from goods with high emissions per job to goods with low emissions per job could simultaneously contribute to reductions in emissions and job creation, hence lowering the emission intensities of jobs and contributing to green jobs creation. Overall, the results suggest that consumption of services should be favoured because of their low emissions per job, and their high labour productivity. On the other hand, goods like electricity, metals, petroleum products and mining in all the countries, and agricultural goods in Brazil, are less preferential in terms of emissions per job. Some goods may be substituted for services and contribute both to lower emissions and more jobs, for example by renting equipment instead of buying. However, there will always be demand for all types of goods to some extent, because services will not be able to satisfy all needs and will require inputs from other sectors in their supply chains. Thus, it may not make sense to shift consumption between the highly aggregated goods covered in this analysis, but rather within the aggregated groups.

Potentials for shifts in consumption within different product groups that can significantly contribute to climate change mitigation have been identified (Girod et al., 2014). Within the agricultural and food product groups, which is especially relevant for Brazil today, shifts from animal-based, especially ruminant, to plant-based diets can contribute significantly to reducing carbon emissions, and so can avoiding air-transported food and vegetables grown in heated green-houses (Girod et al., 2014). The consumption of meat is increasing in most developing countries, suggesting that especially encouraging consumers to limit the growth in meat-based diets in all the BRIICS countries will be important when development continues (Stehfest et al., 2009). It is also recommended for consumers to choose longer-lasting products made out of recycled materials, which could be relevant for changes in some of the high-intensity secondary goods. Avoiding air-travel and using renewable energy powered rather than fossil fuel powered transport options can become more relevant as the countries continue developing and spending more on their incomes on mobility (Hertwich & Peters, 2009), and using renewable energy sources in buildings and retrofitting buildings to be more energy efficient, is relevant because of the growing importance of construction and investments in the BRIICS (Girod et al., 2014). Whether these shifts contribute to growth in jobs as well is less clear, but for example are often renewables more labour-intensive than fossil energy sources, so shifts in energy sources in buildings or transport could contribute to job growth (Fankhauser et al., 2008).

Policy measures to encourage changes in consumer behaviour does exist, for example eco-labelling, financial incentives and environmental standards, and these could be used to promote consumption of goods that are low in emissions and creating important job opportunities. However, actually influencing people's behaviour in practice may be challenging. People may not have the knowledge to choose the most optimal goods for low emissions and job creation, they may worry about differences in costs or quality, or not be capable of realizing how personal decisions may influence climate change or employment creation (Girod et al., 2014; Whitmarsh, Seyfang, & O'Neill, 2011). Thus, it is important to develop policies that efficiently provide consumers with the knowledge and motivation to make optimal decisions (Girod et al., 2014; Whitmarsh et al., 2011).

Population growth has been an important contributor to growth in consumption and hence impacts, enhancing the effect of increased per capita consumption. Still, the population growth rate is on decline in the emerging countries as well as in developed countries, suggesting that this driver will be less important for the growth in impacts in the future. However, the young population structures of India and Indonesia suggest that this driver may still continue being relatively important in those two countries, especially in India who is expected to become the world's largest country by 2024, and the combined effects of their population growth and consumption growth per person in these countries may thus have significant impact on the future growth in global emissions and job creation. These countries will also be important locations of the future global employment, which makes these especially important locations for creating green and decent jobs. The employment growth also has the potential to considerably contribute to economic growth if the countries are able to combine the additions to the labour-force with skill development and productivity improvements (Singh & Dube, 2014). Other aspects of population may also be of importance for the future impacts in the BRIICS, contributing to changes in consumption patterns. For example may the number of households be more important than the number of people, as much of the energy use in households, for example for heating, cooling or lighting, is relatively independent of how many live in the household (Rosa & Dietz, 2012). Household sizes usually decrease over time and with development levels, meaning that as the BRIICS develop, it is likely that the number of households will increase and this could lead to more energy use and emissions (Bongaarts, 2001; Liu, Daily, Ehrlich, & Luck, 2003).

Changes in international trade relations have contributed to reducing the emissions and employment footprints in some of the BRIICS countries', while increasing the carbon footprints in some, because the imports of the BRIICS countries have changed in different manners. They all shifted from a high importance of imports from geographically close regions, to a higher reliance on geographically spread supply chains. Most of the countries' labour footprints were reduced by outsourcing, indicating that they were importing less labour-intensive goods, and imports came from more productive locations, which can be explained by increasing consumption of more sophisticated goods from developed countries. India, Indonesia and South Africa have been reducing their carbon footprints as well by importing goods from more productive regions, while Brazil, China and Russia, more in line with what has been found for developed countries, increased their carbon footprints by outsourcing to other regions with more polluting technologies or buying more emission-intensive products. Since especially the more affluent countries among the BRIICS increased their carbon footprints through changes in import partners, this suggests that they are importing more carbon-intensive products, and the same may happen for the other BRIICS and other developing countries as they continue developing, unless technologies with trading partners become less carbon-intensive, or consumption is changed towards goods that create more jobs and less emissions.

5.1.2. Technological improvements

Most of the BRIICS countries have switched to cleaner energy sources and improving energy efficiency in their production, and this is also visible as reduced carbon intensity of the supply chains producing for their consumption, as large parts of their footprints are still generated in the domestic economy. These changes contributed to slowing down the emission growth from growth in consumption but was not enough to completely offset it. According to Le Quéré et al. (2009) energy efficiency improvements contributed to reducing emissions in emerging countries' production. However, the implementation of renewable energy sources has not significantly contributed to reducing their carbon emissions so far because it has added more capacity rather than replacing fossil fuels. This can explain why technologies of the BRIICS' production are still more carbon-intensive than in developed countries even though they are increasing their use of renewable energy, and suggest that there are potentials for reducing their carbon-intensities by deploying even more renewable energy sources and making sure it replaces carbon-intensive sources rather than complementing it. There is a significant gap between emerging and developed countries' carbon intensities per unit of output, with the exception of Brazil, which can be seen in Figure C 1 for CO_2 emissions. This gap can be interpreted as the minimum potential for continued technology improvements in the BRIICS (Arto et al., 2014). However, Hubacek et al. (2007) show that the necessary technology improvements in India and China to keep emissions stable with expected growth in consumption are unrealistic to achieve. Combined efforts in both changing technologies and consumer behaviour are necessary.

On the global level, it is expected that changes in technology aimed at achieving the Paris Agreement target of temperature rise 2 degrees above pre-industrial levels, like switching from fossil fuels to renewables and improving energy efficiency of buildings, will contribute to net job growth (International Labour Organization, 2018). Jobs would be lost in for example sectors related to fossil fuels, but at the same time new jobs would be created in renewable energy sectors. For the BRIICS to gain benefits from this shift in terms of job growth, it is important to implement policies on developing the skills needed for the new types of green jobs and making sure that the workers employed in carbon-intensive industries are able to be relocated to new professions (International Labour Organization, 2018; Martinez-Fernandez, Hinojosa, & Miranda, 2010), so that carbon-intensive jobs are not lost within the BRIICS and replaced by green jobs in other countries in the supply chains.

By definition of the ILO and UNEP, green jobs need to be decent as well as contributing to preserving the environment (Renner et al., 2008). Labour productivity in all the BRIICS' supply chains are improving, which could be an indication of growing decency of jobs as well. Growing productivity of labour is important for continued development, as this is associated with higher wages, growth in economic activity and hence growth in employment opportunities. The more productive jobs may be of higher quality in terms of for example wages, skills or safety, which are also important aspects of the decency of green jobs. The growing productivities of labour also imply that while emissions per job have been increasing, also the economic value created by each worker is increasing. For continuing the pattern of job creation and productivity growth in emerging countries, transitioning towards especially consumption and production of services are key because of their low emissions per job and high labour-productivity (Ghani & Kharas, 2010; Roncolato & Kucera, 2013).Still, emerging and developing countries are mainly specializing in low-skilled jobs (Los et al., 2014), which means that there is great potential for creating more decent jobs through skill-development strategies.

In terms of products, all should be produced with the most efficient and least carbon-intensive technologies possible. However, there are large differences in the supply chain emissions per job created due to the consumption of various goods, which could highlight in which supply chains there is the most potential to reduce the ratio of emissions to jobs. In all the countries the consumption of electricity, gas and water creates high emissions per job, and significantly higher levels than the consumption of most other goods. As mentioned previously especially shifts from fossil-based energy sources to renewables for producing the electricity could simultaneously reduce the emissions and increase the employment in the supply chains, and the emission reductions could be very significant in many of the BRIICS because of their currently high reliance on coal and other fossil fuels for electricity generation. In Brazil, even though EXIOBASE does not include emissions from land use change, the consumption of agricultural products has one of the highest emission intensities of jobs. The large difference between Brazil and other countries imply that there are potentials for efficiency improvements in the production of agricultural goods produced in Brazil (Lenzen et al., 2013). Also the consumption of mining, metals, minerals and petroleum products are causing high emissions per job and are potential hotspots for technology improvements.

5.2. Exports and green jobs

Over time the BRIICS have engaged increasingly in international trade. Especially China and India have gained an important role as exporters, and the exports are no longer just going to geographically close regions, but are more spread across the world. The growing volume of exports has been the main driver of emissions embodied in the BRIICS' exports. It has also been important for generating employment opportunities and contributed strongly to the economic growth of the BRIICS. As the volume and composition of the exports are to a large extent determined by demand from abroad, the countries should aim at satisfying this demand with as low emissions as possible through technological changes, and while generating significant economic value and employment. To increase the economic benefits received from exports of emission-intensive products, the countries could aim at increasing the value added and jobs embodied in exports. The share of services in generating jobs and value added in the BRIICS are increasing over time, which suggest that providing more services in relation to the exported goods could improve the benefits in terms of jobs and value gained. Value added in exports could also be increased by further processing of for example mined products within the countries rather than relying as much on exports of commodities.

Like with the technology improvements in the supply chains, the technology improvements in the production of exports could come from changes in the inputs used in the production of the exports towards less carbon-intensive intermediates, or by reducing the carbon-intensity of production through efficiency improvements and changes in energy source. The results showed that several of the BRIICS were using inputs with higher carbon-intensity and lower labour-intensity over time, suggesting that their changes in technologies for producing exports currently are contributing to growth in emission intensities of jobs. However, the results only reflect the domestic parts of the supply chains and intermediate inputs, which means that the changes could also reflect that emission-intensive production has been outsourced from developed countries to the BRIICS, while some labour-intensive intermediate production is outsourced to other developing countries. Thus, the full supply chain impacts may not necessarily have changed as much. To avoid carbon leakage, it is important that the BRIICS focus on improving the emissions from their exports through real changes in the way products are produced, and not just by outsourcing emission-intensive production-stages to other developing countries, like developed countries have done before them.

The ranking of sectors according to emissions per job in exports is similar to that of consumption, and this indicates also that the same hotspots in need emission reductions are identified. The emission intensities of jobs in the exports sectors are much higher than those in consumption, indicating that most of the emissions are occurring in the production of these products and not in their upstream suppliers, while more of the employment is generated in other parts of the supply chains. This highlights that it is especially in the production of these goods emissions need to be reduced.

5.3. Uncertainties and limitations

Most of the data in EXIOBASE, both economic accounts and extensions, are more uncertain for developing countries than the data for developed countries. Further, most developing countries except the BRIICS are aggregated into large ROW regions. Several of these regions are important trading partners with the BRIICS, and South-South trade is growing in importance, but the results of analysing these aggregated regions are highly uncertain because of the lack of data for developing countries and the aggregation of many different countries in one. This means that for example the analysis of changes in trading partners is uncertain. Performing similar analyses for less developed countries than the BRIICS could also provide more useful insight into whether other developing countries are following the same development paths, and whether the same measures can be recommended for other countries, or whether other developing countries are following different paths in need of different considerations in policy. The Eora database covers more countries, but is lacking the consistency over time needed to perform SDAs, so there is a trade-off in the choice of database between analysing developing countries and analysing changes over time (Stadler, Wood, et al., 2018).

The time series analysed is relatively short, and what seems like big fluctuations in this analysis might have been interpreted differently if covering a longer time period. On the other hand, the most important events related to trade liberalization started in the beginning of the 1990s, which makes this period an interesting starting point for analysing the role of international trade in the BRIICS. Still, much might have happened with these countries' development and the world economy since 2011. Technology improvements and consumption growth might have been moving fast if following same patterns as found in this thesis, or policies implemented lately may have started affecting technologies, consumer habits or trading relations. But developing IO tables is very time-consuming work, so there are few tables available with more recent data (Simas, 2018). Using IDA instead of SDA would allow to cover a longer time series, as the necessary data is more easily available. However, this approach is not able to cover full supply chain impacts, only territorial or production impacts, and hence an important part of the analysis would be left out.

The choice of indicators for analysing green jobs is also a limitation of this analysis. Only employment and GHG emissions are considered, but there are several other aspects that would be relevant to cover the full perspective of green jobs creation. For example are green jobs defined by the ILO and UNEP as decent, which means that not only the number of jobs are important, but also the quality of them (Renner et al., 2008). This could be covered by also analysing for example wage and skill levels, vulnerability, informality or security in the workplace, but this was considered beyond the scope of this master thesis. For the environmental dimension of green jobs, GHG emissions was chosen as an indicator because of the urgency of stopping climate change, and the interconnectedness of climate with other impacts (Rockström et al., 2009; Steffen et al., 2015). However, other aspects of environment are important for generating green jobs as well, like resource use, other types of pollution, biodiversity and waste (Renner et al., 2008). These impacts might have developed differently than GHG emissions in the BRIICS and including several environmental indicators would hence have provided a stronger analysis and more certain policy recommendations for creating green jobs. Further, the GHG indicator in EXIOBASE does not include emissions from land use change, which could significantly change the results for especially Brazil and Indonesia, from which large shares of emissions come from land use change for agriculture.

Input-output analysis is a top-down approach, making it useful for analysing impacts at the macroeconomic levels. It is however not so useful at the product or sector level, where green jobs are often defined. Its high sector aggregation and assumption of average products make the methodology unable to distinguish between the different requirements of different products within the same sector, or between products produced for exports versus the domestic markets, which could have different input requirements and impacts (Simas, 2018), and could have been useful to cover when for example making recommendations for consumption patterns. Other approaches, for example life cycle assessment (LCA) could be helpful for learning more detailed about green jobs at product levels, production stages or locations. However, this approach does not have a supply chain perspective, so it would risk defining jobs in certain locations or production stages as green even if they were depending on supply chains with high environmental pressures.

6. Conclusion

Export-led growth strategies of the BRIICS countries has contributed to fast economic growth, employment opportunities and consumption growth, allowing these countries to gain higher standards of living and becoming among the important consuming countries in the world economy. However, their growing consumption has been the main driver of growth in their carbon footprints. Although increased consumption has also contributed to increased employment, its role in the growth in jobs has been much lower than in the growth in emissions. The consumption levels of the BRIICS countries are still significantly lower than in advanced countries and will continue to grow as the countries reach higher human development levels. Based on current trajectories, this implies that emission intensities of jobs will continue growing. In order to reduce emission intensities of jobs and contribute to generating green jobs in the BRIICS' production and consumption, consumption growth must be decoupled from emission growth through changes in consumption patterns and technological improvements.

Changes in consumption patterns and international trade relations have not contributed significantly to changes in the BRIICS' footprints in the period 1995 to 2011 compared to other factors, but is likely to be more important in the future, as the BRIICS become richer and start consuming more emission-intensive manufactured goods, larger shares of them imported from abroad. To reduce the emissions per job in the BRIICS' consumption, their development patterns must differ from those of developed countries. There are potentials to achieve this without compromising growth in well-being, for example by developing more energy-efficient infrastructure and appliances, and encouraging consumers to choose long-living products, replace certain goods with services and avoid spending their growing incomes on more carbon-intensive diets and transport modes. The success of changing consumer habits for reducing emissions per job depends on policies' ability to provide consumers with the knowledge and motivation to make these choices.

The analysis has shown that while the technologies of production in the BRIICS countries are improving, they are still highly reliant on more carbon-intensive technologies than more developed countries. Thus, technology transfers from developed countries, for example through the Clean Development Mechanism could contribute significantly to technology improvements in the BRIICS (Arto et al., 2014; Hoekstra et al., 2016; Sakai et al., 2017). The consumption of the developed countries is an important driver of the emissions in the BRIICS' production, which suggests that they could at least be held partially responsible for emission reductions. Further, given the important role of the BRIICS in global emissions in production and consumption, investments in technology improvements in these countries could yield much larger benefits in terms of global emission reductions than similar amounts of money spent on continued improvements in developed countries (Arto & Dietzenbacher, 2014; Hoekstra et al., 2016). These investments could also contribute to green jobs creation if the economic benefits like job creation are explicitly accounted for in the international climate agreements, as recommended by Arto et al. (2014), as this would assure that the emission reductions happens with the lowest costs to the producer.

This analysis provides the historical development of determinants of emissions and employment in the BRIICS and some insight into what to expect from the future if development continues along the same patterns. A natural next step would be to create scenarios for how these drivers is expected to continue developing and what consequences that would have for emissions and employment, and potentially other indicators relevant for green jobs. In addition, scenarios of optimal pathways could then be developed, to inform policy makers on what changes should be implemented to stay within a carbon budget while generating a target number of jobs.

7. References

Akizu-Gardoki, O., Bueno, G., Wiedmann, T., Lopez-Guede, J. M., Arto, I., Hernandez, P., & Moran, D. (2018). Decoupling between human development and energy consumption within footprint accounts. *Journal of Cleaner Production, 202*, 1145-1157. doi:https://doi.org/10.1016/j.jclepro.2018.08.235

Alessandrini, M., Fattouh, B., Ferrarini, B., & Scaramozzino, P. (2011). Tariff liberalization and trade specialization: Lessons from India. *Journal of Comparative Economics, 39*(4), 499-513. doi:https://doi.org/10.1016/j.jce.2011.03.004

Arto, I., & Dietzenbacher, E. (2014). Drivers of the Growth in Global Greenhouse Gas Emissions. *Environmental Science & Technology, 48*(10), 5388-5394. doi:10.1021/es5005347

Arto, I., Rueda-Cantuche, J. M., Andreoni, V., Mongelli, I., & Genty, A. (2014). The game of trading jobs for emissions. *Energy Policy, 66*, 517-525. doi:https://doi.org/10.1016/j.enpol.2013.11.046

Bah, E.-h. (2009). Structural Transformation in Developed and Developing Countries. *Proceedings of the German Development Economics Conference, Frankfurt a.M. 2009*(42).

Beidari, M., Lin, S.-J., & Lewis, C. (2017). Decomposition Analysis of CO2 Emissions from Coal - Sourced Electricity Production in South Africa. *Aerosol and Air Quality Research, 17*(4), 1043-1051. doi:10.4209/aaqr.2016.11.0477

Berg, I. S. (2018). *Green Jobs: Environmental and Social Intensities of Jobs in Emerging Countries*. Unpublished project thesis. Norwegian University of Science and Technology. Trondheim.

Beutel, J. (2008). The input-output framework in the European System of Accounts (ESA 1995). In P. Ritzmann, G. Hanney, & J. Heuschling (Eds.), *Eurostat Manual of Supply, Use and Input-Output Tables*. Luxembourg: Office for Official Publications of the European Communities.

Bongaarts, J. (2001). Household size and composition in the developing world in the 1990s. *Population Studies, 55*(3), 263-279. doi:10.1080/00324720127697

BP. (2019a). Country insight - India. Retrieved from https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/country-and-regional-insights/india.html Accessed April 13th 2019

BP. (2019b). Country insight - Russia. Retrieved from https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/country-and-regional-insights/russia.html Accessed April 13th 2019

Brizga, J., Feng, K., & Hubacek, K. (2013). Drivers of CO2 emissions in the former Soviet Union: A country level IPAT analysis from 1990 to 2010. *Energy, 59*, 743-753. doi:https://doi.org/10.1016/j.energy.2013.07.045

Canuto, O., Haddad, M., & Hanson, G. (2010). Export-Led Growth v2.0. *Economic premise, 3*.

Caporale, G. M., Sova, A., & Sova, R. (2015). Trade flows and trade specialisation: The case of China. *China Economic Review, 34*, 261-273. doi:https://doi.org/10.1016/j.chieco.2015.03.010

Cassim, R. (2003). The pace, nature and impact of trade policy in South Africa in the 1990s. *South African Journal of Economic History, 18*(1-2), 76-95. doi:10.1080/10113430309511155

Chakraborty, D. (2007). *A Structural Decomposition Analysis of Energy Consumption in India*. Paper presented at the 16th International Input-Output Conference, Istanbul, Turkey.

Chen, Z.-M., Ohshita, S., Lenzen, M., Wiedmann, T., Jiborn, M., Chen, B., . . . Liu, Z. (2018). Consumption-based greenhouse gas emissions accounting with capital stock change highlights dynamics of fast-developing countries. *Nature Communications, 9*(1), 3581. doi:10.1038/s41467-018-05905-y

Connolly, R., & Hanson, P. (2012). Russia's Accession to the World Trade Organization. *Eurasian Geography and Economics, 53*(4), 479-501. doi:10.2747/1539-7216.53.4.479

Cox, A., & Foley, B. (2013). *Public Employment Services and green jobs*. Brussels: European Commission.
Das, D. K. (2010). Another perspective on globalization. *Journal of International Trade Law and Policy, 9*(1), 46-63. doi:10.1108/14770021011029609
de Vries, G. J., Erumban, A. A., Timmer, M. P., Voskoboynikov, I., & Wu, H. X. (2012). Deconstructing the BRICs: Structural transformation and aggregate productivity growth. *Journal of Comparative Economics, 40*(2), 211-227. doi:https://doi.org/10.1016/j.jce.2012.02.004
de Vries, G. J., & Ferrarini, B. (2017). What Accounts for the Growth of Carbon Dioxide Emissions in Advanced and Emerging Economies? The Role of Consumption, Technology and Global Supply Chain Participation. *Ecological Economics, 132*, 213-223. doi:https://doi.org/10.1016/j.ecolecon.2016.11.001
Department of Trade and Industry. (n.d.). Integrated National Export Strategy (INES). Retrieved from http://www.dti.gov.za/trade_investment/INES.jsp Accessed May 28th 2019
Dietzenbacher, E., & Los, B. (1998). Structural Decomposition Techniques: Sense and Sensitivity. *Economic Systems Research, 10*(4), 307-324. doi:10.1080/09535319800000023
Dietzenbacher, E., & Los, B. (2000). Structural Decomposition Analyses with Dependent Determinants. *Economic Systems Research, 12*(4), 497-514. doi:10.1080/09535310020003793
Dollery, B., & Snowball, J. (2003). Government failure and state incapacity the South African public sector in the 1990s. *South African Journal of Economic History, 18*(1-2), 310-331. doi:10.1080/10113430309511164
Edwards, L., & Lawrence, R. (2008). South African trade policy matters. Trade performance and trade policy. *Economics of Transition and Institutional Change, 16*(4), 585-608. doi:10.1111/j.1468-0351.2008.00338.x
Elias, S., & Noone, C. (2011). *The Growth and Development of the Indonesian Economy*. RBA Bulletin: Reserve Bank of Australia Retrieved from https://www.rba.gov.au/publications/bulletin/2011/dec/pdf/bu-1211-4.pdf.
Eurostat. (2017). Glossary: Non-profit institutions serving households (NPISH). *Statistics explained.* Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Non-profit_institutions_serving_households_(NPISH) Accessed May 4th 2019
Fan, Y., Liu, L.-C., Wu, G., & Wei, Y.-M. (2006). Analyzing impact factors of CO2 emissions using the STIRPAT model. *Environmental Impact Assessment Review, 26*(4), 377-395. doi:https://doi.org/10.1016/j.eiar.2005.11.007
Fankhauser, S., Sehlleier, F., & Stern, N. (2008). Climate change, innovation and jobs. *Climate Policy, 8*(4), 421-429. doi:10.3763/cpol.2008.0513
Feenstra, R. C. (2007). *Globalization and Its Impact on Labour*. Vienna: The Vienna Institute for International Economic Studies.
Feng, K., Davis, S. J., Sun, L., & Hubacek, K. (2015). Drivers of the US CO2 emissions 1997–2013. *Nature Communications, 6*, 7714. doi:10.1038/ncomms8714
Feridhanusetyawan, T., & Pangestu, M. (2003). Indonesian Trade Liberalization: Estimating the Gains. *Bulletin of Indonesian Economic Studies, 39*(1), 51-74. doi:10.1080/00074910302008
Ferreira, P. C., & Rossi, J. L. (2003). New Evidence from Brazil on Trade Liberalization and Productivity Growth. *International Economic Review, 44*(4), 1383-1405. doi:10.1111/1468-2354.t01-1-00114
Fisher, N., & Downes, G. (n.d.). South Africa. Retrieved from https://www.iea.org/ciab/South_Africa_Role_Coal_Energy_Security.pdf Accessed June 1st 2019
Ghani, E., & Kharas, H. (2010). *The Service Revolution*. The World Bank, Poverty Reduction and Economic Management Network Retrieved from http://documents.worldbank.org/curated/en/752251468337914853/pdf/545950BRI0EP140Box349423B01PUBLIC1.pdf.

Girod, B., & De Haan, P. (2010). More or Better? A Model for Changes in Household Greenhouse Gas Emissions due to Higher Income. *Journal of Industrial Ecology, 14*(1), 31-49. doi:10.1111/j.1530-9290.2009.00202.x

Girod, B., van Vuuren, D. P., & Hertwich, E. G. (2014). Climate policy through changing consumption choices: Options and obstacles for reducing greenhouse gas emissions. *Global Environmental Change, 25*, 5-15. doi:https://doi.org/10.1016/j.gloenvcha.2014.01.004

Goswami, A. G., Gupta, P., Mattoo, A., & Sáez, S. (2012). A Cross-Country Analysis of Service Exports: Lessons from India. In A. G. Goswami, A. Mattoo, & S. Sáez (Eds.), *Exporting Services. A Developing Country Perspective*. Washington D.C.: The World Bank.

Guan, D., Peters, G. P., Weber, C. L., & Hubacek, K. (2009). Journey to world top emitter: An analysis of the driving forces of China's recent CO2 emissions surge. *Geophysical Research Letters, 36*(4). doi:10.1029/2008GL036540

Hertwich, E. G., & Peters, G. P. (2009). Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology, 43*(16), 6414-6420. doi:10.1021/es803496a

Hoekstra, R., Michel, B., & Suh, S. (2016). The emission cost of international sourcing: using structural decomposition analysis to calculate the contribution of international sourcing to CO2-emission growth. *Economic Systems Research, 28*(2), 151-167. doi:10.1080/09535314.2016.1166099

Hoekstra, R., & van den Bergh, J. C. J. M. (2003). Comparing structural decomposition analysis and index. *Energy Economics, 25*(1), 39-64. doi:https://doi.org/10.1016/S0140-9883(02)00059-2

Hubacek, K., Guan, D., & Barua, A. (2007). Changing lifestyles and consumption patterns in developing countries: A scenario analysis for China and India. *Futures, 39*(9), 1084-1096. doi:https://doi.org/10.1016/j.futures.2007.03.010

Inglesi-Lotz, R., & Blignaut, J. N. (2011). South Africa’s electricity consumption: A sectoral decomposition analysis. *Applied Energy, 88*(12), 4779-4784. doi:https://doi.org/10.1016/j.apenergy.2011.06.018

Inglesi-Lotz, R., & Pouris, A. (2012). Energy efficiency in South Africa: A decomposition exercise. *Energy, 42*(1), 113-120. doi:https://doi.org/10.1016/j.energy.2012.04.002

International Energy Agency. (2017). World Energy Outlook 2017: China. Retrieved from https://www.iea.org/weo/china/ Accessed April 13th 2019

International Energy Agency. (2019a). Brazil. Retrieved from https://www.iea.org/countries/Brazil/ Accessed April 13th 2019

International Energy Agency. (2019b). Indonesia. Retrieved from https://www.iea.org/countries/Indonesia/ Accessed April 13th 2019

International Energy Agency. (2019c). South Africa. Retrieved from https://www.iea.org/countries/South%20Africa/ Accessed April 13th 2019

International Labour Organization. (2018). *World Employment and Social Outlook 2018: Greening with jobs*. Geneva: International Labour Office.

International Monetary Fund. (2008). *Globalization: A Brief Overview*. Washington D.C: Policy Communication Division Retrieved from https://www.imf.org/external/np/exr/ib/2008/053008.htm.

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.), (pp. 151). Geneva, Switzerland: IPCC.

Ivakhnyuk, I. (2009). *The Russian Migration Policy and its Impact on Human Development: The Historical Perspective*. Retrieved from http://hdr.undp.org/sites/default/files/hdrp_2009_14.pdf.

Jones, S., & Inggs, J. (2003). The South African economy in the 1990s. *South African Journal of Economic History, 18*(1-2), 1-15. doi:10.1080/10113430309511151

Jorgenson, A. K., & Clark, B. (2013). The Relationship between National-Level Carbon Dioxide Emissions and Population Size: An Assessment of Regional and Temporal

Variation, 1960–2005. *PLOS ONE, 8*(2), e57107. doi:10.1371/journal.pone.0057107
Kingstone, P. (2012). Brazil's reliance on commodity exports threatens its medium- and long-term growth prospects. Retrieved from https://www.americasquarterly.org/kingstone Accessed May 24th 2019
Kitzes, J. (2013). An Introduction to Environmentally-Extended Input-Output Analysis. *Resources, 2*(4), 489.
Kopidou, D., Tsakanikas, A., & Diakoulaki, D. (2016). Common trends and drivers of CO2 emissions and employment: a decomposition analysis in the industrial sector of selected European Union countries. *Journal of Cleaner Production, 112*, 4159-4172. doi:https://doi.org/10.1016/j.jclepro.2015.06.079
Kuenen, J., Usubiaga, A., Acosta-Fernández, J., & Merciai, S. (2018). EXIOBASE 3 - Supporting Information for air emission accounts (S3). Supporting information for Stadler, K. et al 2018. EXIOBASE 3: Developing a time series of detailed Environmentally Extended Multi-Regional Input-Output tables. *Journal of Industrial Ecology, 22*(3).
Kurniawan, R., Sugiawan, Y., & Managi, S. (2018). Cleaner energy conversion and household emission decomposition analysis in Indonesia. *Journal of Cleaner Production, 201*, 334-342. doi:https://doi.org/10.1016/j.jclepro.2018.08.051
Lan, J., & Malik, A. (2013). Structural Decomposition Analysis of the Energy Consumption in China and Russia — An Application of the Eora MRIO Database In J. Murray & M. Lenzen (Eds.), *Sustainability Practitioner's Guide to Multi-Regional Input-Output Analysis*: Common Ground Publishing.
Le Quéré, C., Raupach, M. R., Canadell, J. G., Marland, G., Bopp, L., Ciais, P., . . . Woodward, F. I. (2009). Trends in the sources and sinks of carbon dioxide. *Nature Geoscience, 2*, 831. doi:10.1038/ngeo689
Lee, K., & Oh, W. (2006). Analysis of CO2 emissions in APEC countries: A time-series and a cross-sectional decomposition using the log mean Divisia method. *Energy Policy, 34*(17), 2779-2787. doi:https://doi.org/10.1016/j.enpol.2005.04.019
Lenzen, M., Pade, L.-L., & Munksgaard, J. (2004). CO2 Multipliers in Multi-region Input-Output Models. *Economic Systems Research, 16*(4), 391-412. doi:10.1080/0953531042000304272
Lenzen, M., Schaeffer, R., Karstensen, J., & Peters, G. P. (2013). Drivers of change in Brazil's carbon dioxide emissions. *Climatic Change, 121*(4), 815-824. doi:10.1007/s10584-013-0930-1
Liu, J., Daily, G. C., Ehrlich, P. R., & Luck, G. W. (2003). Effects of household dynamics on resource consumption and biodiversity. *Nature, 421*(6922), 530-533. doi:10.1038/nature01359
Los, B., Timmer, M., & de Vries, G. (2014). *The Demand for Skills 1995-2008: A Global Supply Chain Perspective*. OECD Publishing Retrieved from https://EconPapers.repec.org/RePEc:oec:ecoaaa:1141-en.
Los, B., Timmer, M. P., & de Vries, G. J. (2015). How important are exports for job growth in China? A demand side analysis. *Journal of Comparative Economics, 43*(1), 19-32. doi:https://doi.org/10.1016/j.jce.2014.11.007
Malik, A., & Lan, J. (2016). The role of outsourcing in driving global carbon emissions. *Economic Systems Research, 28*(2), 168-182. doi:10.1080/09535314.2016.1172475
Martinez-Fernandez, C., Hinojosa, C., & Miranda, G. (2010). *Greening Jobs and Skills. Labour Market Implications of Addressing Climate Change*: OECD.
McMillan, M., & Headey, D. (2014). Introduction – Understanding Structural Transformation in Africa. *World Development, 63*, 1-10. doi:https://doi.org/10.1016/j.worlddev.2014.02.007
McMillan, M., Rodrik, D., & Verduzco-Gallo, Í. (2014). Globalization, Structural Change, and Productivity Growth, with an Update on Africa. *World Development, 63*, 11-32. doi:https://doi.org/10.1016/j.worlddev.2013.10.012

Meng, J., Mi, Z., Guan, D., Li, J., Tao, S., Li, Y., . . . Davis, S. J. (2018). The rise of South–South trade and its effect on global CO2 emissions. *Nature Communications, 9*(1), 1871. doi:10.1038/s41467-018-04337-y

Miller, R. E., & Blair, P. D. (2009). *Input-Output Analysis: Foundations and Extensions* (2nd ed.). Cambridge: Cambridge University Press.

Minx, J. C., Baiocchi, G., Peters, G. P., Weber, C. L., Guan, D., & Hubacek, K. (2011). A "Carbonizing Dragon": China's Fast Growing CO2 Emissions Revisited. *Environmental Science & Technology, 45*(21), 9144-9153. doi:10.1021/es201497m

Nassif, A., Feijó, C., & Araújo, E. (2014). Structural change and economic development: is Brazil catching up or falling behind? *Cambridge Journal of Economics, 39*(5), 1307-1332. doi:10.1093/cje/beu052

Nayyar, D. (2016). BRICS, developing countries and global governance. *Third World Quarterly, 37*(4), 575-591. doi:10.1080/01436597.2015.1116365

Nübler, I. (2016). *New technologies: A jobless future or a golden age of job creation?* (Research department working paper No.13, ISSN: 2412-4589 (web pdf)). Geneva: ILO.

OECD. (2012). *Summary of Country Responses to the OECD Questionnaire on Green Jobs, Supporting Material for Chapter 4 of the 2012 OECD Employment Outlook*. Retrieved from https://www.oecd.org/els/emp/Chap%204%20Web%20Annex.pdf

OECD. (2018). Trade in Value Added: Brazil. Retrieved from https://www.oecd.org/industry/ind/TIVA-2018-Brazil.pdf Accessed

OECD. (n.d.). *Trade in Value-Added: Concepts, Methodologies and Challenges (Joint OECD-WTO note)*. Retrieved from https://www.oecd.org/sti/ind/49894138.pdf.

Olanrewaju, O. A. (2018). Energy consumption in South African industry: A decomposition analysis using the LMDI approach. *Energy & Environment, 29*(2), 232-244. doi:10.1177/0958305X17745364

Pan, C., Peters, G. P., Andrew, R. M., Korsbakken, J. I., Li, S., Zhou, D., & Zhou, P. (2017). Emissions embodied in global trade have plateaued due to structural changes in China. *Earth's Future, 5*(9), 934-946. doi:doi:10.1002/2017EF000625

Paul, S., & Bhattacharya, R. N. (2004). CO2 emission from energy use in India: a decomposition analysis. *Energy Policy, 32*(5), 585-593. doi:https://doi.org/10.1016/S0301-4215(02)00311-7

Peters, G. P. (2007). *Opportunities and challenges for environmental MRIO modelling: Illustrations with the GTAP database*. Paper presented at the 16th International Input-Output Conference, Istanbul, Turket.

Peters, G. P. (2008). From production-based to consumption-based national emission inventories. *Ecological Economics, 65*(1), 13-23. doi:https://doi.org/10.1016/j.ecolecon.2007.10.014

Peters, G. P., Minx, J. C., Weber, C. L., & Edenhofer, O. (2011). Growth in emission transfers via international trade from 1990 to 2008. *Proceedings of the National Academy of Sciences, 108*(21), 8903.

Peters, G. P., Weber, C. L., Guan, D., & Hubacek, K. (2007). China's Growing CO2 EmissionsA Race between Increasing Consumption and Efficiency Gains. *Environmental Science & Technology, 41*(17), 5939-5944. doi:10.1021/es070108f

Polenske, K. R. (2004). Leontief's «magnificent machine» and other contributions to applied economics. In E. Dietzenbacher & M. L. Lahr (Eds.), *Wassily Leontief and Input-Output Economics*. Cambridge, UK: Cambridge University Press.

Raupach, M. R., Marland, G., Ciais, P., Le Quéré, C., Canadell, J. G., Klepper, G., & Field, C. B. (2007). Global and regional drivers of accelerating CO₂ emissions. *Proceedings of the National Academy of Sciences, 104*(24), 10288. doi:10.1073/pnas.0700609104

Renner, M., Sweeney, S., & Kubit, J. (2008). *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*. Nairobi: Publishing Services Section United Nations Office at Nairobi (UNON).

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin Iii, F. S., Lambin, E. F., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature, 461*, 472. doi:10.1038/461472a

Rodrik, D. (2006a). Understanding South Africa’s Economic Puzzles. *National Bureau of Economic Research Working Paper Series, No. 12565*. doi:10.3386/w12565

Rodrik, D. (2006b). What's So Special about China's Exports? *China & World Economy, 14*(5), 1-19. doi:10.1111/j.1749-124X.2006.00038.x

Roncolato, L., & Kucera, D. (2013). Structural drivers of productivity and employment growth: a decomposition analysis for 81 countries. *Cambridge Journal of Economics, 38*(2), 399-424. doi:10.1093/cje/bet044

Rosa, E. A., & Dietz, T. (2012). Human drivers of national greenhouse-gas emissions. *Nature Climate Change, 2*, 581. doi:10.1038/nclimate1506

Sakai, M., Owen, A., & Barrett, J. (2017). The UK’s Emissions and Employment Footprints: Exploring the Trade-Offs. *Sustainability, 9*(7), 1242.

Schandl, H., Hatfield-Dodds, S., Wiedmann, T., Geschke, A., Cai, Y., West, J., . . . Owen, A. (2016). Decoupling global environmental pressure and economic growth: scenarios for energy use, materials use and carbon emissions. *Journal of Cleaner Production, 132*(Supplement C), 45-56. doi:https://doi.org/10.1016/j.jclepro.2015.06.100

Shi, A. (2003). The impact of population pressure on global carbon dioxide emissions, 1975–1996: evidence from pooled cross-country data. *Ecological Economics, 44*(1), 29-42. doi:https://doi.org/10.1016/S0921-8009(02)00223-9

Simas, M. (2018). *The social and environmental dimensions of global value chains.* (PhD), Norwegian University of Science and Technology, Trondheim.

Simas, M., Hertwich, E., & Wood, R. (2018). Drivers of employment and carbon emissions in global value chains. *Unsubmitted manuscript*.

Simas, M., Stadler, K., & Wood, R. (2018). EXIOBASE 3 - Supporting Information for labor accounts (S7). Supporting information for: Stadler, K. et al. 2018. EXIOBASE 3: Developing a time series of detailed Environmentally Extended Multi-Regional Input-Output tables. *Journal of Industrial Ecology, 22*(3).

Simas, M., Wood, R., & Hertwich, E. (2015). Labor Embodied in Trade. *Journal of Industrial Ecology, 19*(3), 343-356. doi:doi:10.1111/jiec.12187

Singh, S., & Dube, M. (2014). BRICS and the World Order: A Beginner’s Guide. *Available at SSRN: https://ssrn.com/abstract=2443652 or http://dx.doi.org/10.2139/ssrn.2443652*.

Stadler, K., Bulavskaya, T., Södersten, C.-J., Schmidt, S., & Wood, R. (2018). EXIOBASE 3 - Supporting Information for the monetary accounts (S1). Supporting information for: Stadler, K. et al. 2018. EXIOBASE 3: Developing a time series of detailed Environmentally Extended Multi-Regional Input-Output tables. *Journal of Industrial Ecology, 22*(3).

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., . . . Tukker, A. (2018). EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. *Journal of Industrial Ecology, 22*(3), 502-515. doi:10.1111/jiec.12715

Steffen, W., Crutzen, P. J., & McNeill, J. R. (2007). *The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature* (Vol. 36): SPIE.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. doi:10.1126/science.1259855

Stehfest, E., Bouwman, L., van Vuuren, D. P., den Elzen, M. G. J., Eickhout, B., & Kabat, P. (2009). Climate benefits of changing diet. *Climatic Change, 95*(1), 83-102. doi:10.1007/s10584-008-9534-6

Steinberger, J. K., & Roberts, J. T. (2010). From constraint to sufficiency: The decoupling of energy and carbon from human needs, 1975–2005. *Ecological Economics, 70*(2), 425-433. doi:https://doi.org/10.1016/j.ecolecon.2010.09.014

Stiglitz, J. E. (2003). Globalization and growth in emerging markets and the New Economy. *Journal of Policy Modeling*(25), 505-524. doi:doi: 10.1016/S0161-8938(03)00043-7
Su, B., & Ang, B. W. (2012). Structural decomposition analysis applied to energy and emissions: Some methodological developments. *Energy Economics, 34*(1), 177-188. doi:https://doi.org/10.1016/j.eneco.2011.10.009
Tang, X., McLellan, B. C., Zhang, B., Snowden, S., & Höök, M. (2016). Trade-off analysis between embodied energy exports and employment creation in China. *Journal of Cleaner Production, 134*, 310-319. doi:https://doi.org/10.1016/j.jclepro.2015.08.122
Templet, P. H. (1993). The Emissions-to-Jobs Ratio: A Tool for Evaluating Pollution Control. *Environ. Sci. Technol., 27*(5), 810-812.
Tukker, A., Bulavskaya, T., Giljum, S., de Koning, A., Lutter, S., Simas, M., . . . Wood, R. (2016). Environmental and resource footprints in a global context: Europe's structural deficit in resource endowments. *Global Environmental Change, 40*, 171-181. doi:https://doi.org/10.1016/j.gloenvcha.2016.07.002
UNCTAD. (2018). *Key Statistics and Trends in International Trade 2017*. New York and Geneva: United Nations Retrieved from https://unctad.org/en/PublicationsLibrary/ditctab2017d6_en.pdf.
UNDP. (2018). *Technical notes for Human Development Indices and Indicators: 2018 Statistical update*. Retrieved from http://hdr.undp.org/sites/default/files/hdr2018_technical_notes.pdf.
United Nations. (2015a). *Population 2030. Demographic challenges and opportunities for sustainable development planning*. New York: United Nations Retrieved from https://www.un.org/en/development/desa/population/publications/pdf/trends/Population2030.pdf.
United Nations. (2015b). *Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1* Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld/publication
United Nations. (2017a). The impact of population momentum on future population growth. *Population facts.* Retrieved from https://population.un.org/wpp/Publications/Files/PopFacts_2017-4_Population-Momentum.pdf Accessed April 14th 2019
United Nations. (2017b). *World population prospects: The 2017 Revision. Key findings and advance tables*. Department of Economic and Social Affairs, Population Division.
Wang, H., Ang, B. W., & Su, B. (2017). Assessing drivers of economy-wide energy use and emissions: IDA versus SDA. *Energy Policy, 107*, 585-599. doi:https://doi.org/10.1016/j.enpol.2017.05.034
Wei, T. (2011). What STIRPAT tells about effects of population and affluence on the environment? *Ecological Economics, 72*, 70-74. doi:https://doi.org/10.1016/j.ecolecon.2011.10.015
Whitmarsh, L., Seyfang, G., & O'Neill, S. (2011). Public engagement with carbon and climate change: To what extent is the public 'carbon capable'? *Global Environmental Change, 21*(1), 56-65. doi:https://doi.org/10.1016/j.gloenvcha.2010.07.011
World Bank. (2018). Gross domestic product 2017. Retrieved from http://databank.worldbank.org/data/download/GDP.pdf Accessed April 11th 2019
World Bank. (2019a). CO2 emissions (kg per 2010 US$ of GDP). Retrieved from https://data.worldbank.org/indicator/EN.ATM.CO2E.KD.GD Accessed June 3rd 2019
World Bank. (2019b). GDP per capita growth (annual %). Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG Accessed April 12th 2019
World Bank. (2019c). Population growth (annual %). Retrieved from https://data.worldbank.org/indicator/SP.POP.GROW Accessed April 12th 2019

World Bank. (2019d). Population, total. Retrieved from https://data.worldbank.org/indicator/SP.POP.TOTL?year_high_desc=true Accessed April 26th 2019

World Bank. (2019e). The World Bank in Indonesia. Overview. Retrieved from https://www.worldbank.org/en/country/indonesia/overview Accessed May 28th 2019

World Bank Group. (2018). *Modest Growth Ahead. 39 Russia Economic Report*. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/29913/127254-WP-PUBLIC-ADD-SERIES-JunefinalRussiaEconomicReportENG.pdf?sequence=1&isAllowed=y.

Xu, M., Li, R., Crittenden, J. C., & Chen, Y. (2011). CO2 emissions embodied in China's exports from 2002 to 2008: A structural decomposition analysis. *Energy Policy, 39*(11), 7381-7388. doi:https://doi.org/10.1016/j.enpol.2011.08.068

Xu, Y., & Dietzenbacher, E. (2014). A structural decomposition analysis of the emissions embodied in trade. *Ecological Economics, 101*, 10-20. doi:https://doi.org/10.1016/j.ecolecon.2014.02.015

Yao, C., Feng, K., & Hubacek, K. (2015). Driving forces of CO2 emissions in the G20 countries: An index decomposition analysis from 1971 to 2010. *Ecological Informatics, 26*, 93-100. doi:https://doi.org/10.1016/j.ecoinf.2014.02.003

York, R., Rosa, E. A., & Dietz, T. (2003). STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics, 46*(3), 351-365. doi:https://doi.org/10.1016/S0921-8009(03)00188-5

Appendix A - Supporting information for methodology

Table A 1 – Aggregation of 17 product categories to 5

	Primary goods	Electrical & machinery	Electricity, gas & water	Construction	Other secondary goods	Services
Agriculture, hunting, forestry & fishing	X					
Mining & quarrying	X					
Food production, beverages & tobacco	X					
Textiles, leather & wearing apparel					X	
Wood, paper & publishing					X	
Petroleum, chemicals & non-metallic mineral products					X	
Metal & metal products					X	
Electrical & machinery		X				
Transport equipment					X	
Manufacturing & recycling					X	
Electricity, gas & water			X			
Construction				X		
Sale, maintenance & repair of vehicles; fuel; trade; hotels & restaurants						X
Transport						X
Post & telecommunications						X
Financial intermediation & business activity						X
Public administration; education; health; recreation; other services						X

Table A 2 - Characterization of GHG emissions to CO_2 equivalents

Emission	**Characterization factor**
CO_2 - combustion – air	1
CH_4 - combustion – air	28
N_2O - combustion – air	265
CH_4 - non combustion - Extraction/production of (natural) gas – air	28
CH_4 - non combustion - Extraction/production of crude oil – air	28
CH_4 - non combustion - Mining of antracite – air	28
CH_4 - non combustion - Mining of bituminous coal – air	28
CH_4 - non combustion - Mining of coking coal - air	28
CH_4 - non combustion - Mining of lignite (brown coal) - air	28
CH_4 - non combustion - Mining of sub-bituminous coal - air	28
CH_4 - non combustion - Oil refinery - air	28
CO_2 - non combustion - Cement production - air	1
CO_2 - non combustion - Lime production - air	1
SF_6 - air	23500
HFC - air	1
PFC - air	1
CH_4 - agriculture - air	28
CO_2 - agriculture - peat decay - air	1
N_2O - agriculture - air	265
CH_4 - waste - air	28
CO_2 - waste - biogenic – air	1
CO_2 - waste - fossil - air	1

Appendix B – Additional results

Table B 1 - Average annual growth rates in impacts between 1995 and 2011

	Employment			GHG		
	Domestic	Exports	Imports	Domestic	Exports	Imports
China	0,5 %	1,8 %	35,6 %	10 %	12 %	43 %
Brazil	1,5 %	6,5 %	13,5 %	4 %	14 %	11 %
India	0,0 %	8,5 %	24,1 %	4 %	14 %	34 %
Russia	1,4 %	0,2 %	1,2 %	1 %	-1 %	4 %
Indonesia	1,7 %	4,0 %	7,7 %	4 %	9 %	5 %
South Africa	-0,2 %	1,3 %	5,0 %	1 %	8 %	9 %

Figure B 1 - GHG distribution on domestic economy, imports and exports for the BRIICS in 1995 and 2011

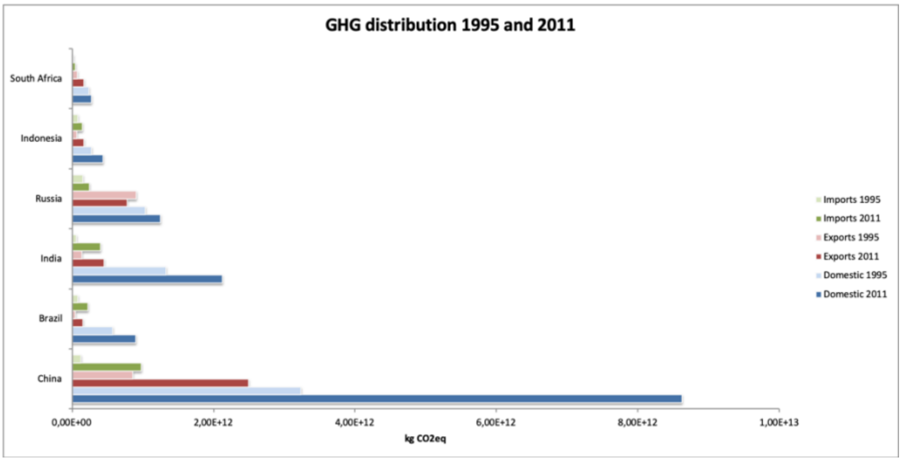


Figure B 2 – Employment distribution on domestic economy, imports and exports for the BRIICS in 1995 and 2011

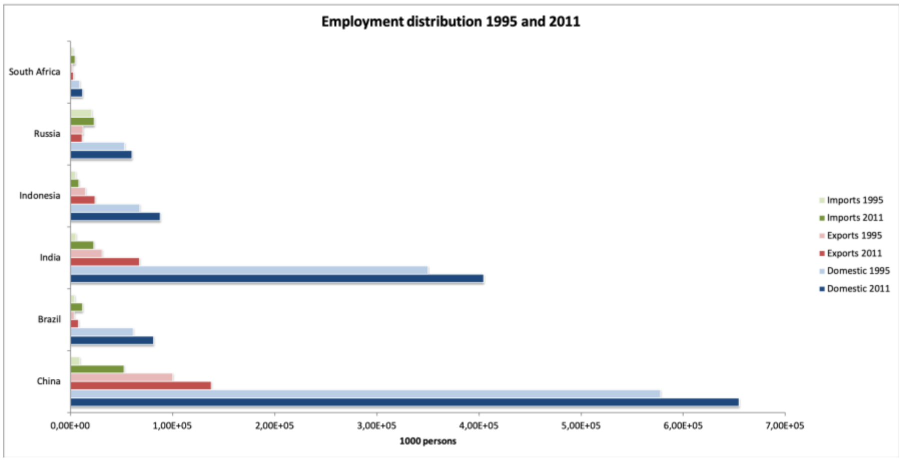


Figure B 3 - Distribution of labour and carbon footprints by consumption categories of the BRIICS in 1995

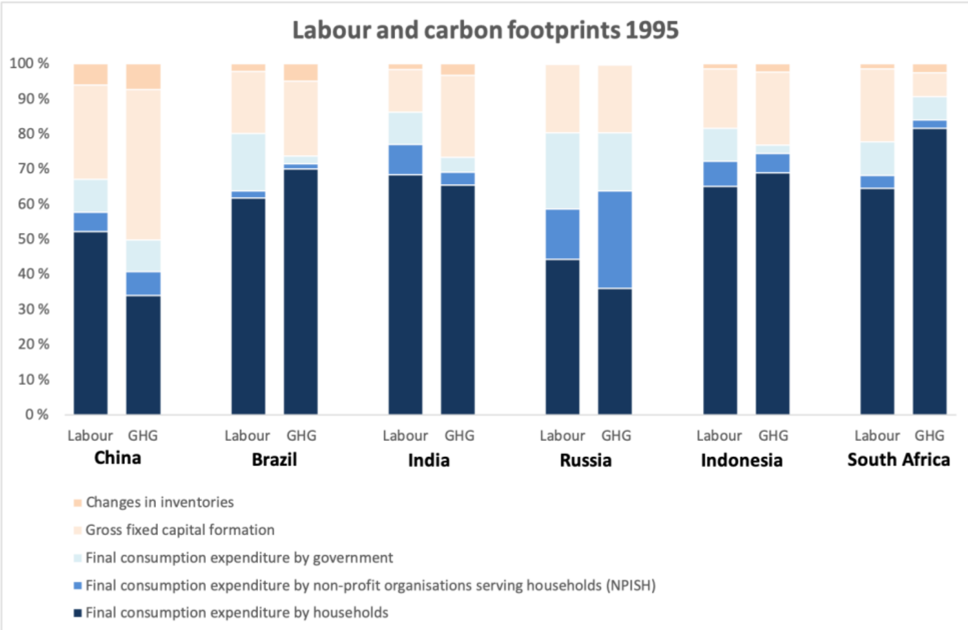


Figure B 4 - Distribution of emission and employment footprints by consumption categories in the EU28 and USA in 1995 and 2011

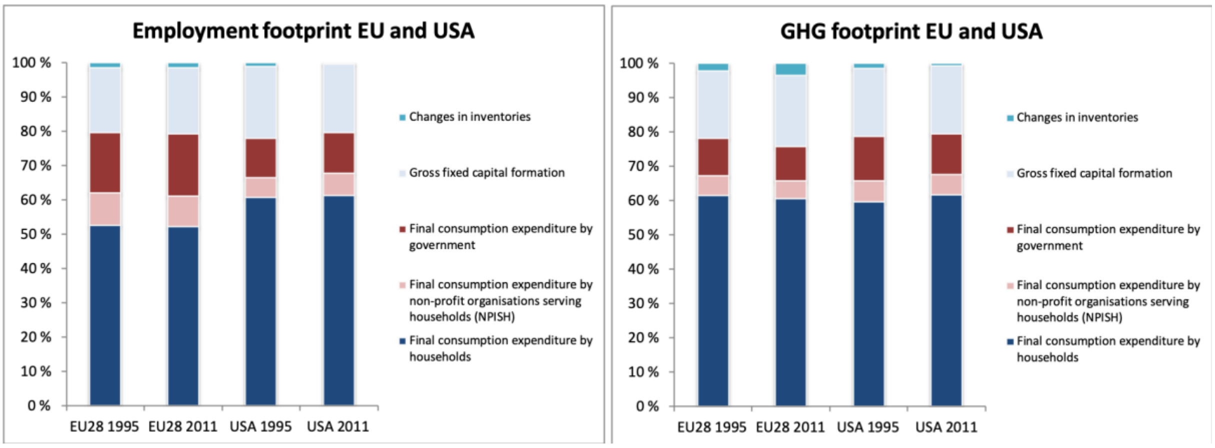


Figure B 5- Distribution of the labour and carbon footprints by consumption goods in the BRIICS in 2011

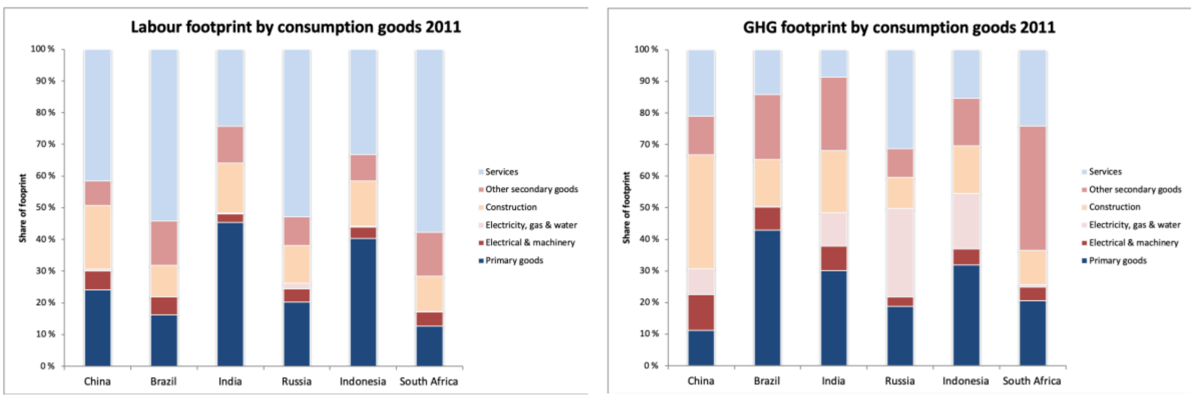


Figure B 6 - Distribution of the labour and carbon footprints by consumption goods in the BRIICS in 1995

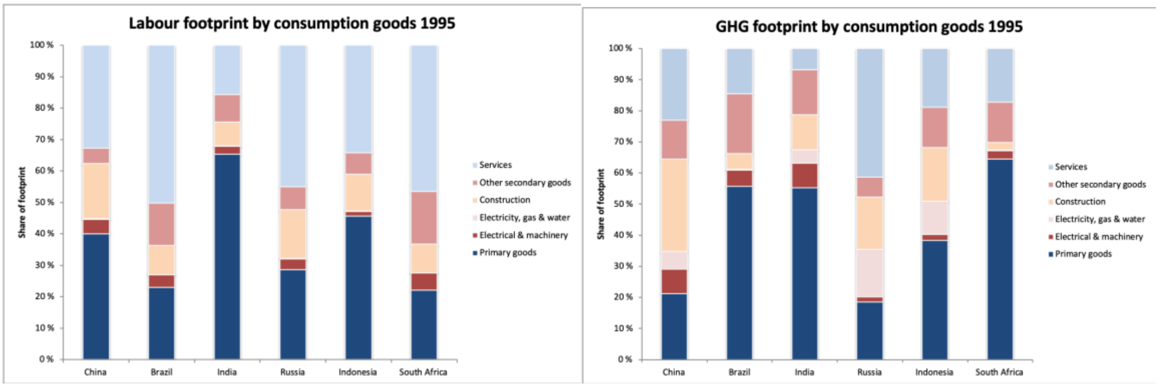


Figure B 7 - GHG emissions, employment and value added in exports production in 1995 and 2011

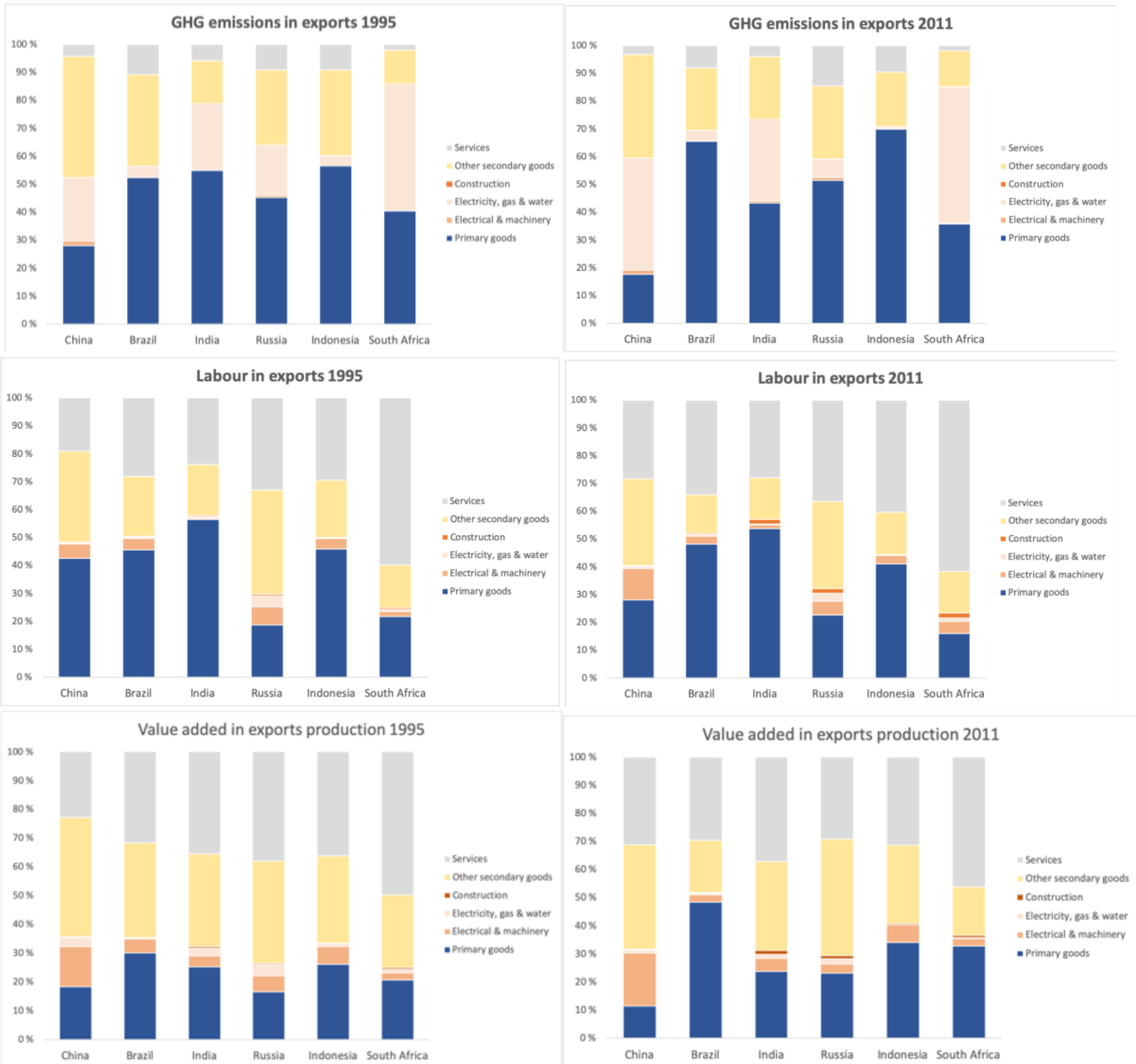
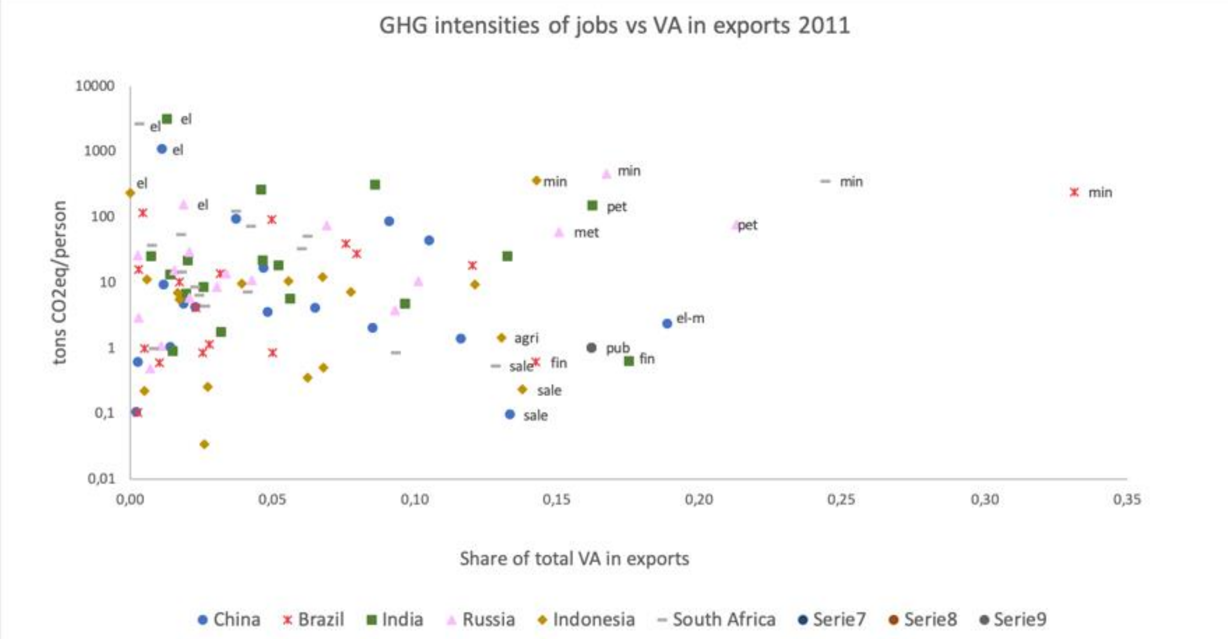


Figure B 8 – GHG intensities of jobs versus value added in exports production 2011



el - electricity, gas and water, min - mining and quarrying, el-m - electrical and machinery, pet - petroleum, chemicals and non-metallic mineral products, fin - financial intermediation and business activity, sale - sale, maintenance & repair of vehicles; fuel; trade; hotels and restaurants, agri - agriculture, hunting, forestry and fishing

Figure B 9 - More detailed results for drivers of employment in consumption of the BRIICS. Determinants are defined in Table 3-1.

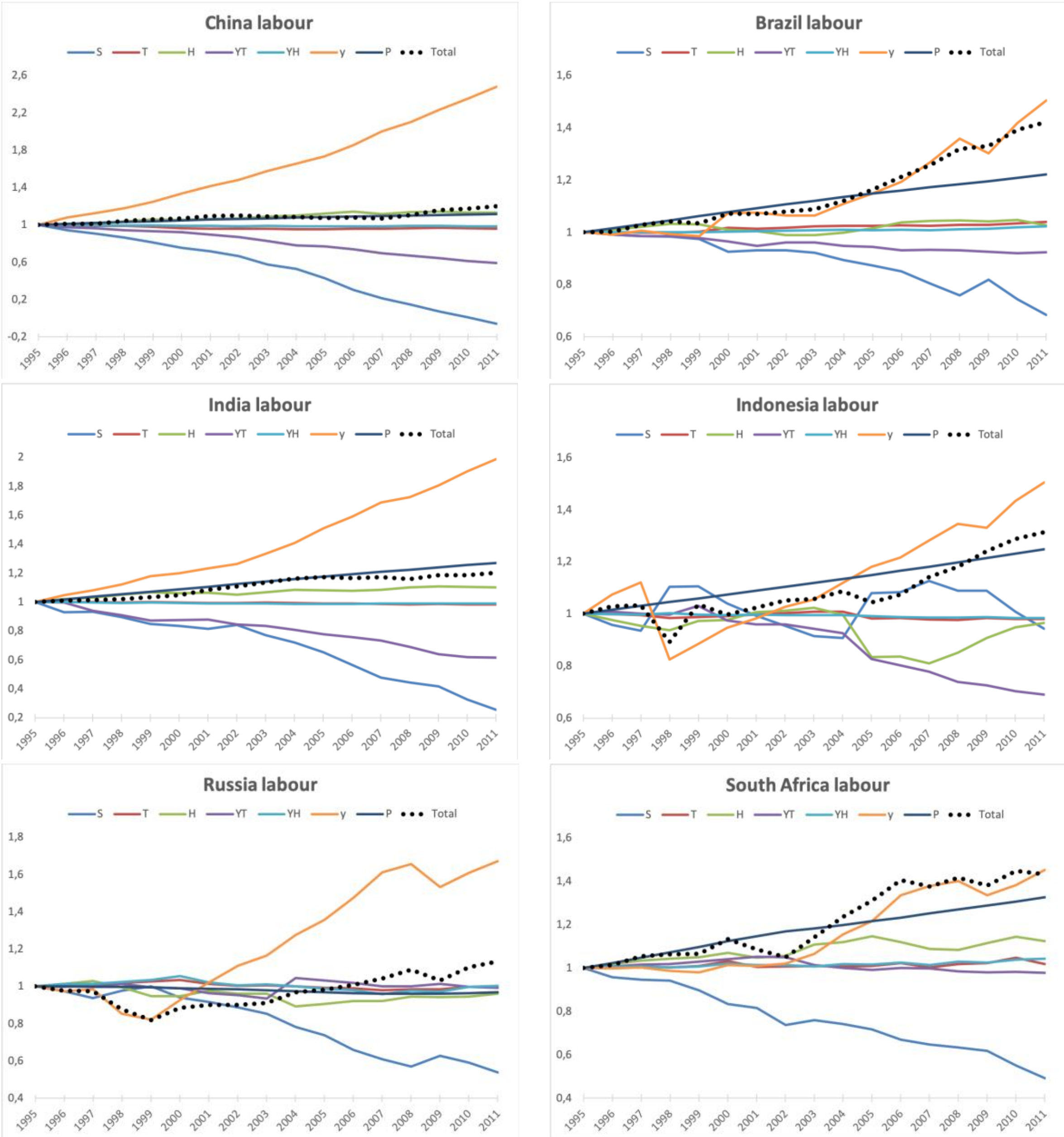


Figure B 10 – More detailed results for drivers of GHG emissions in consumption of the BRIICS. Determinants are defined in Table 3-1.

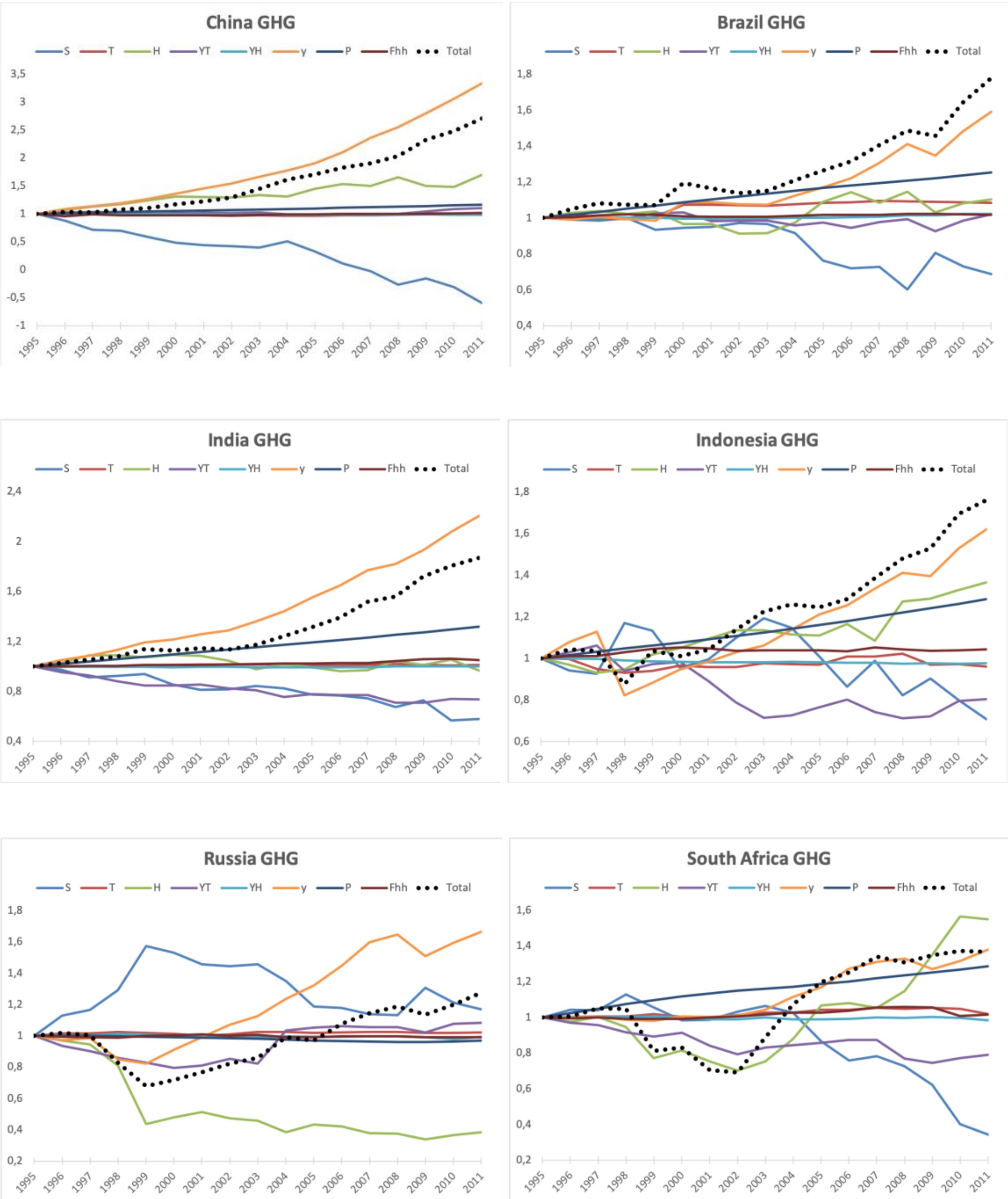


Figure B 11 – More detailed results for drivers of labour in exports of the BRIICS

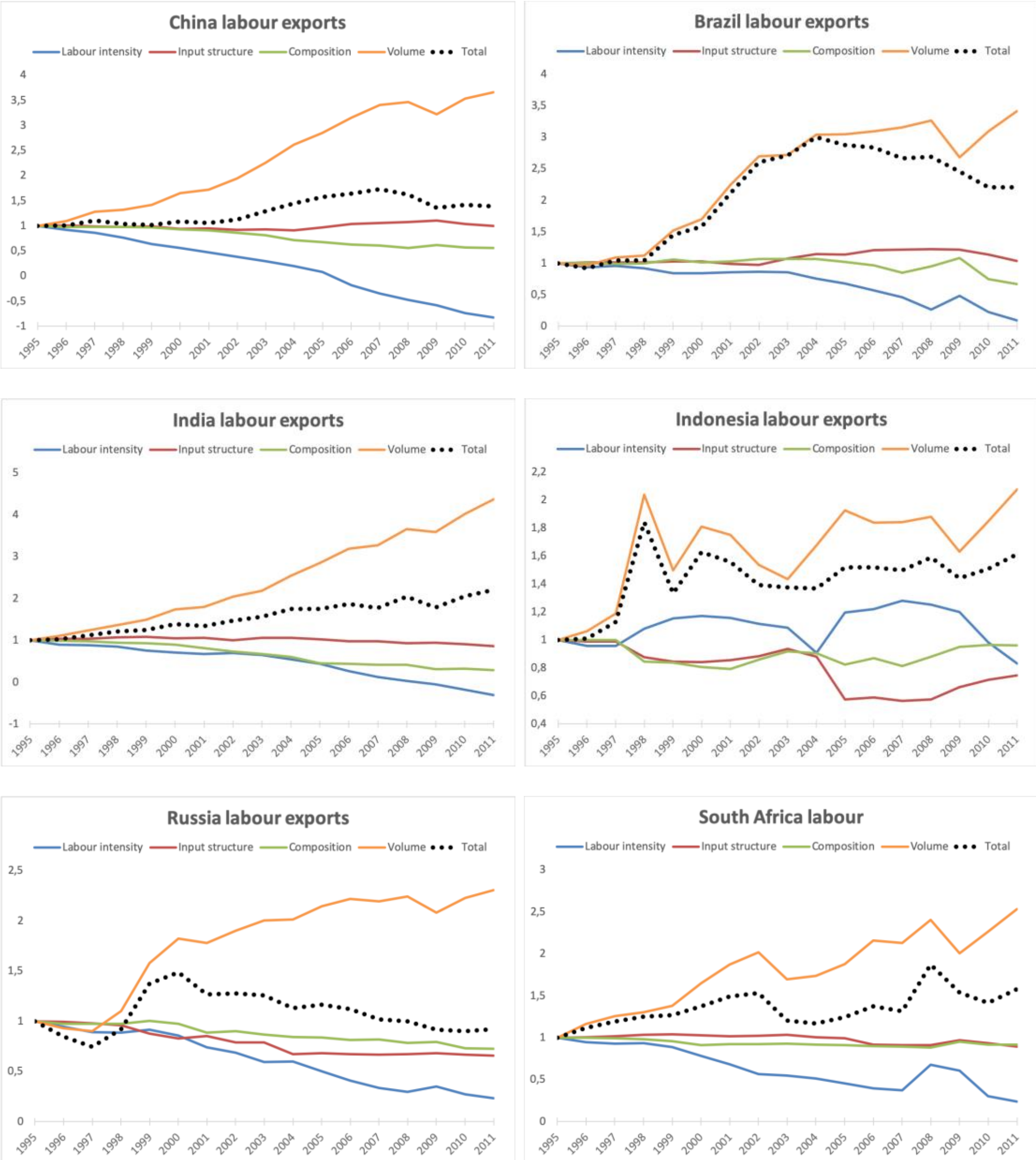
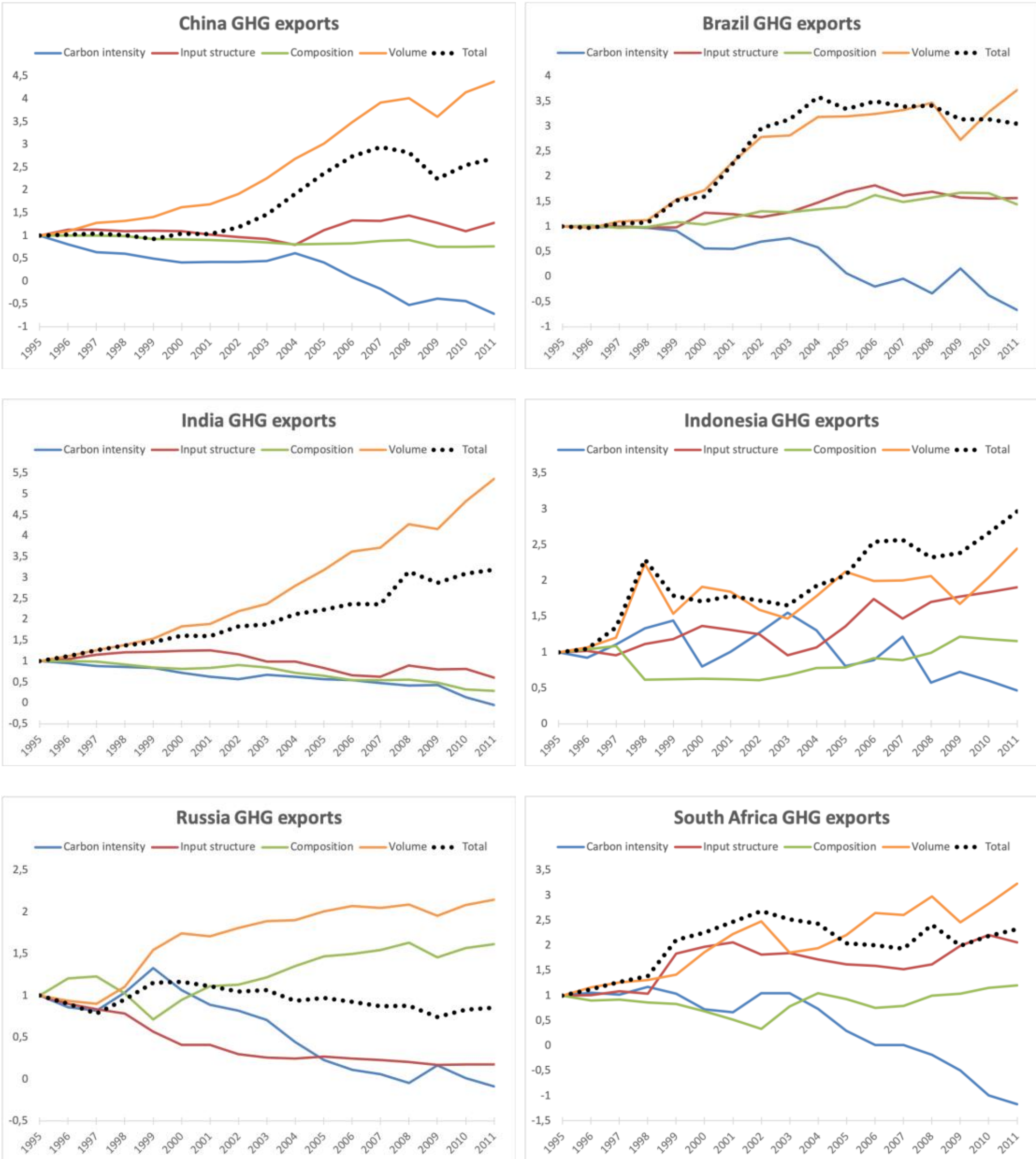
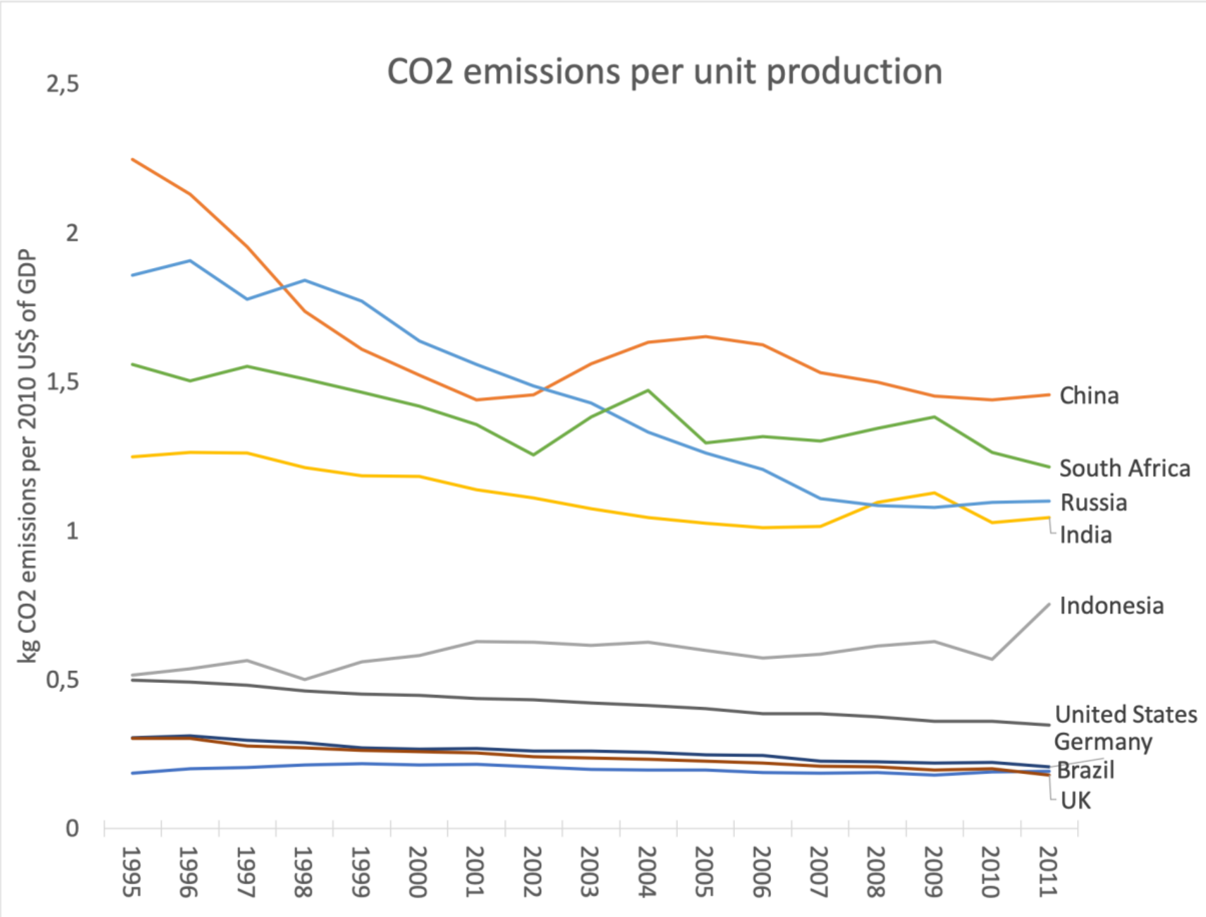


Figure B 12 – More detailed results for drivers of GHG emissions in exports of the BRIICS



Appendix C - Supporting information for discussion

Figure C 1 – CO_2 emissions per unit of GDP in the BRIICS and selected developed countries for comparison (World Bank, 2019a)



NTNU
Norwegian University of
Science and Technology