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Social Indicators for Use with Multi-Regional Input-Output Analysis

A thesis submitted in fulfillment of

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by

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STATEMENT ON PUBLICATION AND JOINT CONTRIBUTION

The chapters in this thesis are in publication or under review for peer reviewed journals and books, with the exceptions of the Introduction and Conclusion. The following is a statement of my contribution to each chapter.

Chapter 1: Introduction

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Chapter 5: Coltan: A Study of Environmental Justice and Global Supply Chains

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Chapter 6: The Contribution of Input-Output Analysis to Understanding Impacts of Consumption – A Review Update

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Chapter 7: A Social Footprint of Nations: A comparative study of the Impact of Business on People

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Chapter 8: Conclusion

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SUMMARY

Accounting for social impacts in supply chain analysis is of increasing importance. Global trade has increased significantly since 1970, as has inequality. Institutions such as the International Monetary Fund have recently highlighted social impacts, such as inequality and social cohesion, as primary risks for the global economy. As global supply chains have become more prevalent, the need to understand and analyse these supply chains has also grown. Excellent work on quantitative analysis of environmental impacts in supply chains has taken place in the past two decades, with one study reporting the existence of thousands of references in academic journals on environmental supply chain performance. However, relatively few methodologies have been applied to quantitative analysis of social impacts in supply chains. From the discovery of child labour in Nike's sportswear supply chains in the 1990s to the deaths of more than 1000 people employed in the garment industry in the collapse of Rana Plaza in Bangladesh, social impacts in supply chains are high profile and of concern to consumers, business and governments.

This thesis considers how social indicators for supply chain analysis can be developed through the use of socially extended multi-regional input-output analysis. Chapter 1 provides an introduction and context for this thesis. Chapter 2 considers the history of social accounting and the different means for measuring social impacts. Chapter 3 looks at quantitative accounting for social-economic indicators and the development of national accounts, particularly in reference to standardised collection of data for social-economic indicators and socially-extended input-output analysis. Chapter 4 presents a case study and methodological analysis using deaths in the Democratic Republic of Congo as a social indicator for the electronics supply chain. Chapter 5 analyses the results of the same case study for a different purpose and considers how enumerating social impacts in upstream supply chains can influence environmental and social justice actions in downstream supply chains. Chapter 6 provides a review of input-output analysis used as a tool for analysing consumption since 2010, and in particular the increase in use of this methodology for analysing global supply chains. Chapter 7 proposes the use of a suite of quantitative social indicators for analysis in the form of a social footprint. Chapter 8 provides a conclusion. This thesis tracks the author's driving interest in understanding social impacts in global supply chains, from understanding where our current statistics originated from, to potential methods of analysis and how they can be used, to a final proposal of a composite social indicator (a social footprint) for supply chain analysis using the multi-regional input output methodology.

1. INTRODUCTION

BACKGROUND

Accounting for social impacts within a supply chain can be a complex process. As trade barriers are reduced and global trade increases supply chains have become more complex and more opaque because of the number of parties that can be involved. Organisations need to understand not only where supply chains start and finish, but also the social (and environmental) impacts that occur along the way. The business drivers for understanding production and supply chains include reporting requirements, legal requirements, chain of custody certification, risk management, business to business and consumer pressure, logistics and efficiency and ethics. Businesses are finding that supply chain impacts are material to their operations and hence should be included in management indicators and organisational reporting.

Increasingly, corporate responsibility and legislation will require accounting for sustainability in production and supply chains, particularly those extending into high social (and environmental) risk areas. Although there has been a greater focus in literature on environmental impacts of supply chains, it is the social impacts that tend to create a negative image that companies can find difficult to shake off. One of the first major publicity scandals relating to social impacts in a global supply chain was that of the sporting brand Nike. The use of child labour in its production supply chain for the sewing of footballs is well known. Many years after this case was first publicised, its legacy remains in the public perception even though Nike has since put in place processes to ensure that labour within their supply chain is in line with if not better international labour standards (Birch 2012).

Even for sustainability reporting businesses now need to focus on the impacts within their supply chains. The G4 Reporting Guidelines released in 2013 by the Global Reporting Initiative[1] have an increased emphasis on materiality and supply chain management compared with previous guidelines, with supply chain disclosures now required as standard. Relatively few tools enable the analysis of global production and supply chains, and even fewer offer the ability to analyse multiple supply chains at once.

The purpose of this thesis is to investigate a methodology to help determine the scale and existence of social impacts within global supply chains. Where social data exists sourced from research into production (for example, the number of hours worked by children to stitch footballs) how can it be used to quantify the responsibility for impact in consumption? We can get the upstream data, usually through means such as social audits, surveys or questionnaires. What we do not understand is how much of that social impact we consumers are responsible for consuming, once the product has gone through numerous supply chain paths to different countries. This thesis seeks to test a methodology to connect social impacts occurring upstream with the countries of consumption downstream. The research question addressed in this thesis is whether **data-driven techniques using multi-regional input-output analysis (MRIOA) are able to provide information for assessing supply chain accountability with respect to social impacts**. In particular, this thesis seeks to address the lack of quantitative assessment of social impacts in supply chains by providing examples of how social impacts can be measured and tracked through supply chains, using MRIOA. This introduction will examine current methods for accounting for social impacts in supply chains, explain in greater detail what MRIOA is, explain the evolution of this thesis and outline how the chapters fit together as a coherent whole document.

[1] https://www.globalreporting.org/reporting/g4

MEASURING SOCIAL IMPACTS IN SUPPLY CHAINS

The social responsibility of business has many interpretations. These range from Milton Friedman's assertion that business has no social responsibility, only responsibility to increase profitability within the rules of the game (Friedman 1970) to John Elkington redefining business accounting through a triple bottom line approach (Elkington 1998) and many theories in between and beyond. Gray argues that there is no evidence to support liberal economics as described by Friedman, and that the economic system of accounting and reporting on which it is based has fundamental flaws, as evidenced, for example, by the increasing inequality gap between rich and poor and the decline of the state of the environment (Gray 2006; 796). The social responsibility of business is often referred to as corporate social responsibility. Corporate social responsibility (CSR) was simply defined by McWilliams and Siegal (2001; 117) as "...actions which appear to further some social good, beyond the interests of the firm and that which is required by law". Contributing to the theory of CSR was Freeman's work on the management of stakeholder expectations for strategic outcomes and subsequent development of the ideas around stakeholder identification (Freeman 1984, Mitchell et al. 1997). If we assume that businesses do have a responsibility for the social impacts they generate (through supply or employment), then robust assessment and accounting methodologies are required.

There is increasing importance being placed on accounting for sustainability impacts in supply chains (Wolf 2011, Erol et al. 2011, Quadra et al. 2009, Corbiere-Nicollier et al. 2011). The benefits of managing supply chain impacts have been well noted for competitive advantage, improved efficiency and operations (Lee 2002, Kim 2006, Kim 2009, Klibi et al. 2010, Lainez et al. 2009, Mefford 2009, Mosovsky et al. 2000, Nyaga et al. 2010, Prado-Prado 2009). To date, most of the research on this subject has been into 'greening' supply chains or improving environmental outcomes. Social accounting is most frequently addressed as part of social and environmental accounting (SEA) or sustainability accounting, rather than addressing social accounting on its own. Shaw et al (2010) found over 2000 references on the ISI Web of Science database when searching for 'environmental supply chain performance'. The body of work on managing the social sustainability of supply chains is smaller, but increasing. It often focuses on how businesses manage their supply chain accountability, accounting and reporting, linking CSR activities with supply chain management (Spence and Bourlakis 2009, Kortelainen 2008, Awaysheh and Klassen 2010).

In their assessment of sustainability accounting and reporting, Burritt and Schaltegger (2010) divide the literature into two main bodies: the critical theorists who propose that sustainability accounting does nothing to support planetary sustainability, and that reporting can in fact deflect away from or even obfuscate the true destruction caused by business in the pursuit of economic growth; and those who support the development of sustainability accounting if it provides internal or external stakeholders with 'useful and high quality' information (p833) for managerial focussed accounting. However, data provided for sustainability accounting is not always useful or high quality. There is a lack of quantification of social accounting, in particular. In many instances, sustainability reporting is used purely to drive branding message rather than demonstrate real commitment to improved environmental or social outcomes. Hopwood illustrates 'green advertising' using the example of oil companies and the rhetoric between their actions and words (Hopwood 2009; 438-439).

A gap in this body of work is that few SEA methodologies rely on economic accounting tools to account for social and environmental impacts, despite purporting to be accounting. The time has come to fill this gap, and this thesis will demonstrate a way in which economic tools can be used to account for social impacts. In their review of the past 20 years of development of SEA literature, Gray and Laughlin (2012) do not discuss the evolution of input-output analysis (IOA)

as a tool for social or environmental accounting. IOA is used in some forms of social accounting (such as social accounting matrices) but the use of environmentally and socially extended MRIOA is relatively new. If financial reporting and SEA "derive from fundamentally different views of the world" (Gray 2006; 794) then surely the use of socially and environmentally extended MRIOA can go some way towards bringing these worlds together and bridging the gap. MRIOA is based on economic accounts and trade flows, usually in US dollars. The ability to associate physical accounts (such as carbon emissions or deaths) as inputs to economic trade is part of the ingenuity of MRIOA. In his ground-breaking work developing the input-output framework (that was eventually recognised with a Nobel Prize in 1973), Wassily Leontief realised that you could use input-output analysis to model how much pollution input was required to produce a certain output (a car, for example). In this way, in this thesis I explore how social impacts are also an input to production.

Boundary definition and data availability are difficulties that arise with many methods of social or environmental analysis. For example some of the challenges for social life cycle assessment are data availability and the definition of the assessment scope (Lehmann et al. 2013). Data requirements and boundaries are an important consideration for accuracy in SEA (Burritt and Schaltegger 2010, Gray and Laughlin 2012, Aras and Crowther 2009). A single physical supply chain audit of a global supply chain will be limited by time, availability, cost and access. However, MRIOA can take into account over 5 million supply chains in one calculation from upstream production to downstream consumption. Boundaries do need to be drawn, but not as tightly as required with most other methodologies. This power of MRIOA has only become available since around 2008, because of improved computational powers used in the construction and data population of global MRIO databases (Kanemoto and Murray 2013).

Hopwood (2009) argues that calculation and new forms of accounting should be a feature of achieving a greater harmony between human endeavours and planetary sustainability. Hopwood uses the carbon emissions market as an example of a link between accounting and the environment. MRIO models are regularly used to model both consumer and producer carbon emissions because the methodology allows for calculation of a complete carbon footprint (Wiedmann 2009). Chapter 7 demonstrates the use of this methodology applied to social accounting, using the social impacts of work instead of greenhouse gas emissions to develop a social footprint. This thesis demonstrates that socially-extended MRIO accounts provide the accounting field with a tool that has an accounting/economics foundation that can be combined with qualitative analysis including case study analysis and qualitative textual analysis to understanding the impacts of global trade and its supply chains.

REVIEW OF SOCIAL ACCOUNTING METHODOLOGIES

APPROACH

In this section contrasts the MRIOA approach with popular methods for social supply chain analysis through a literature review. Three popular methodologies used by business for social accounting in supply chains were identified - supplier social audits, third party verification or certification schemes, and procurement activities. The methodologies were not found to be mutually exclusive, and often combinations of all three were used. All of these processes are used to assist business to maintain or promote certain social outcomes, generally relating to human rights and labour conditions, within multiple tiers of the supply chain.

SUPPLIER SOCIAL AUDITS

Supplier social audits are generally conducted on behalf of the purchaser of a product or service. They involve sending a representative (either directly employed or a third party) to a place of production within the supply chain. These audits often take place in factories (Kortelainen 2008) but can also travel down the supply chain to primary producers, particularly in the food or textile industries (Miller 2011, Spence and Bourlakis 2009). As Hannah Jones, Head of Global Corporate Social Responsibility at Nike is quoted as saying of social audits *"All monitoring does is reveal the issues. It doesn't solve them. The reasons for excessive overtime, for example, are horribly complicated. You have to do system analysis. You have to do 'root cause' analysis*." (Foley 2012). However, revealing the issues and what is happening on the ground is a significant advantage of this method over all other methods discussed.

THIRD PARTY CERTIFICATION AND VERIFICATION

Another methodology for pursuing social accountability in supply chain management by business is using a third party certification or chain of custody certification to established standards. For example, Fairtrade is a third party certification process that focuses on guaranteed prices and codes of conduct as a system for sustainable supply chain management (Welford et al. 2003, Vermeulen and Seuring 2009). Compliance with the key International Labour Organisation (ILO) conventions is commonly found in standards with a social impact focus such as Fairtrade, Ethical Trading Initiative, United Nations Global Compact and the Forestry Stewardship Council standard. Chain of custody certification can be costly and time consuming (Suryani et al. 2011) with varying results due to the different certification systems available and their requirements. The benefit of chain of custody certification or third party verification is that it can enable a buyer (or consumer) to know that each link of a supply chain has been verified to a certain known standard, or know that the production of a good has been audited to a known standard, without actually physically auditing the supply chain (as outlined in the previous section). The standards tend to be developed by the industry as well as social and environmental non-governmental organisations (NGOs) and as a consequence have requirements for high environmental and social outcomes.

PURCHASING AND PROCUREMENT PRACTICES

Purchasing and procurement practices are other approaches used for accountability in supply chain management to gather supply chain information and control supply chain practices. Roberts (2003) highlights that there has been an increasing trend to outsource business processes and activities to suppliers and subcontractors, placing responsibility for corporate governance aspects such as environmental and social impact risk management within procurement functions. Standards, such as BS8903:2010 – Principles and Framework for Procuring Sustainably, non-governmental organisation (NGO) and government advice are increasingly providing guidance to organisations on how to take social issues into account in the procurement process. For example, the United Nations Global Compact, a code of conduct containing social standards aimed at improving CSR, will have an influence on business supply chain management and accountability (Leisinger 2007, Garsten and Jacobsson 2011, Marinilka Barros and Cao 2011, Janney et al. 2009, Rasche 2009). However studies have also shown that using CSR policies in supply chain programs can have a negative effect on businesses, particularly on small to medium enterprises, due to issues such as increased cost and time burdens (Ciliberti et al. 2011, Villena et al. 2011, Baden et al. 2011). The benefits of using purchasing and procurement policies are that they are lower cost and easier to implement because they generally don't involve site visits or third party verification (although both of these can still take place). They can also be applied easily across a number of supply chains.

MULTI-REGIONAL INPUT-OUTPUT ANALYSIS

MRIOA is the use of multiple input-output tables, arranged in a matrix database, to analyse economic trades and flows across multiple countries or regions. Individual input-output tables demonstrate, on a monetary basis, the inputs to industry sectors required to produce goods or services and the outputs of each industry sector, and the interrelationships for one country or region. Thus an input-output table shows the flows of money through different sectors of the economy to final consumption (Murray and Wood 2010). Most countries produce their own input-output tables at regular intervals, with data collected in accordance with the System of National Accounts (United Nations Statistics Division 2009). MRIO databases have evolved as computing power increases and are usually developed by research centres, with less than ten databases currently in development and use globally (Murray and Lenzen 2013).

Several different methods of analysis have been used in this thesis, including using hybrid LCA-MRIOA and the use of MRIOA footprinting. In the case study of coltan (chapters 4 and 5) a hybrid LCA-MRIOA approach was used by combining detailed information from a LCA approach to the production and use of coltan with MRIOA. This hybrid approach has been used previously (Wiedmann et al. 2011, Suh and Nakamura 2007, Suh 2004, Bullard et al. 1978), but not with social impact data. The coltan study used sector disaggregation to provide supply chain analysis as well as associating a social satellite account. A satellite account is an account containing relevant data that is linked to but separate from the main IO table/s (United Nations Statistics Division 2008), generally linking physical (or non-monetary) accounts such as water or carbon emissions to economic (monetary) accounts. Disaggregating a sector using detailed data gathered through research makes it possible to trace a very specific supply chain through an economy using input-output analysis (Lenzen 2011, Liu et al. 2012). The study used in chapters 4 and 5 follow the money flows from one industry sector to the other through to final consumption using structural path analysis, as used by Wood and Lenzen (2009), Suh and Heijungs (2007) and Lenzen(2006) to analyse supply chains.

There are many uses for MRIOA. Examples include assessing environmental impacts such as the energy, emissions or embodied carbon intensity of sectors of the economy or industry sectors (Treloar 1997, Virtanen et al. 2011, Zhou 2010, Liu et al. 2012), and consumption based accounting, particularly in reference to accounting for Greenhouse Gas Emissions (Wiedmann 2009). MRIOA is also well established for assessing policy decisions and alternative scenarios, such as assessing the costs and benefits of alternative forms of energy (Wiedmann et al. 2011), producer/consumer responsibility (Lenzen et al. 2007) and consumption and production (Wiedmann and Barrett 2011). However, the application of MRIOA to social supply chain analysis has to date been limited. The UNEP/SETAC guidelines on social LCA and the associated methodological sheets (Benoit-Norris et al. 2011) make a significant contribution to understanding the detailed social impacts of products, but not necessarily whole supply chains.

The use of satellite accounts for special purposes in input-output analysis, such as measuring health or environmental impacts, is outlined in the System of National Accounts (United Nations Statistics Division 2008; Chapter 29). Different approaches to assessing social impacts using combined LCA and MRIOA have been used, such as by Rugani et al (2012). Studies linking MRIOA and social impacts are emerging particularly in relation to inequality between global trading partners (Alsamawi et al. 2014, Prell et al. 2014) and assessing product supply chains using the GTAP MRIO database and associated Social Hotspot Database (Benoit-Norris et al. 2012). However the combination of using sector disaggregation, social satellite accounts and structural path analysis has not been common to MRIOA for revealing detailed social supply chain impacts. This thesis will demonstrate the value of MRIOA for better understanding social impacts in supply chains and for evaluating the social impacts of global trade.

There are many benefits of using MRIOA for supply chain analysis. The ability to trace millions of supply chains throughout the world has come about through the painstaking creation of detailed MRIO databases based on national economic accounts, and satellite accounts developed through other data sources such those collected by the World Bank, World Health Organisation, International Labour Organisation. To trace these supply chains through economic data without the use of MRIOA would be almost impossible, and certainly very time consuming. The scope provided by MRIOA is very large. Using economic data can provide rigor to the process of tracing social impacts in supply chains.

Another benefit of using a MRIO database is the ability to conduct an analysis with only partial data. The availability of a small amount of detailed data (explained as superior data in Chapter 4) will provide a better result than its absence. This represents the combination of life cycle data with MRIOA. The inclusion of detailed data upstream in the supply chain enables this information to be allocated proportionally along the supply chain and accounted for downstream at the point of consumption.

The cost of research using an MRIO model (where available) is significantly less than that required for a physical supply chain audit, and may reveal enough information to allow business or government to focus their efforts. The applicability of MRIOA to a range of sustainability issues in supply chain accounting is significant – the approach can be used to model the supply chain of products of concern, such as palm oil, or to model supply chains where production methods are of concern, such as child labour. The process is already in use for the quantification of environmental impacts and lends itself well to further application in investigation of social supply chain issues particularly at an industry level.

There are, however, limitations to use of MRIOA for supply chain analysis. Limitations with input-output analysis are well understood. For example, if a business understands its size in proportion to the industry sector, it can estimate responsibility proportionally for the chosen indicator. However, if a business does not behave in an average manner (e.g. it uses only recycled material inputs to production) the results will need to be adjusted accordingly. IOA is based on macroeconomic data, collected in accordance with the SNA (United Nations Statistics Division 2009). A nation's accounts depend on that nation being able to accurately collate data relating to labour, employment, income, taxes, trade and even population. However, where a country has a significant informal (or black market) economy or a population employed in non-paid work (e.g. domestic labour, subsistence farming), the SNA is unable to account for that economic activity (Waring 1988). Data inaccuracies will also affect this (e.g. under-reporting of workplace accidents). This limitation is in part addressed by the use of superior data in the case study of coltan, providing more detailed input on social impacts than are otherwise unaccounted for in national accounts. The proposed system of social-economic accounts in Chapter 3 also contributes to the development of robust data. Future work on socially extended MRIOA will need to address the shortcomings of current data collection in accordance with the SNA.

It is important to note that most IO tables are in monetary terms (usually US$ for MRIO databases). The results thus can suffer from bias from price effects (e.g. using monetary analysis the environmental impacts of a $50 special fare for a flight will be reported as 1/10th that of the same flight at its normal $500 fare). Flows into and out of some financial sectors, for example, may be reported as highly environmentally or socially intensive even though the actual physical flows in to/out of these sectors are in fact small. In the case of a trace element such as coltan these price biases may have a large effect, thus the results in this thesis should be used as provisional estimates and guidance for further research, not as authoritative final values. The detailed research undertaken to put together the possible supply chains for coltan out of the

DRC in 2000 does, however, prove that the methodology is able to be applied to social impacts if sufficiently detailed data are available.

Further discussions on IO analysis limitations and strengths in general such as sector averages, uncertainties of data, scope and double counting can be found in texts such as by Murray and Wood (2010). Further details regarding the data quality of the Eora MRIO tables, including data optimisation, standard deviation settings and the confidence of UN Main Aggregates and Official Country Data and UN Comtrade data can be found in Lenzen et al (2012).

As with most data analysis, MRIOA is retrospective. Information provided by national statistical organisations may be two to five years behind the current year. As with any computational method, researchers must understand the information being analysed and fed into the system for analysis, as well as have the ability to interpret the results. However, MRIOA has been used successfully over defined time periods to help identify trends and predict future activity eg (Barrett et al. 2013).

Unlike physical audits, verified certification or even working with supply chain partners through procurement processes, MRIOA does not reveal the actual social situation on the ground. For example for the coltan case study the superior data collected was based primarily on UN Security Council reports where a team of experts was on the ground, conducting interviews, following up information leads and assessing impacts. Without actual data collected from sites of interest, whether by the researchers themselves or other organisations (in this case most often intergovernmental or NGO organisations), assumptions must be made, which reduces the certainty of the results. Where analysis is used with superior data certainty, for example as provided directly by an industry sector or by an interested NGO, the results of analysis will have a higher degree of certainty. This point brings together the importance of collaboration for MRIOA – collaboration in the methodology development, collaboration in getting detailed data, collaboration in sharing results and collaboration for using those results for human development.

THE EVOLUTION OF IDEAS – MY PERSONAL JOURNEY THROUGHOUT THIS THESIS

BACKGROUND

The research question of whether *data-driven techniques using multi-regional input-output analysis are able to provide information for assessing supply chain accountability with respect to social impacts* came about through my work in sustainable procurement. Having worked as a practitioner of sustainable procurement and supply chain management for business and government for many years in Australia and in the UK, I could see that there was a gap in the availability of quantitative data for use in social impact analysis of supply chains. A workshop on triple bottom line accounting with Integrated Sustainability Analysis (ISA) at the University of Sydney in 2008 introduced me to the concepts of input-output analysis (IOA) and its application to sustainability accounting. Although few social data sets were being used at that time, it became apparent that by using similar methodologies to those used for extended environmental analysis using IOA, this method could be used for social analysis. This line of query led me to undertaking a PhD with ISA to investigate Social Indicators for Supply Chain Analysis using Multi-Regional Input Output Analysis. This thesis was started in 2010. The chapters of the thesis have been presented here in such a way that it flows as a logical sequence to a reader. However, my thinking on this topic did not flow as logically. The following section explains the evolution

of my thoughts as I sought to answer my initial research question. As such, chapters will be referred to in this section out of sequential order but in order of evolution.

Starting my career as an engineer, my concern was for the built environment and primarily how the built environment and the natural environment interact. Although there was some attempt in my undergraduate training to mould well-rounded engineers, my focus was primarily in the fields of engineering and science. The importance of the role of people in the interaction between the built and natural environments was not emphasised nor was its importance highlighted. This issue was raised in a recent *Nature* article, discussing the importance of embedding social awareness in science, technology, engineering and mathematics professions to develop technical solutions that serve humanity (Cech 2014).

LOST IN THE CONGO

The first area of research for this thesis was looking at mining of coltan in the Democratic Republic of Congo (DRC) and considering how to account for the social impacts in global supply chains. In collaboration with others, this research was conducted through the use of disaggregated high resolution MRIOA to enumerate the production and global supply chains for coltan. The social impact of mining coltan was developed as an indicator through looking at the death toll in the Democratic Republic of Congo (DRC) associated with the civil war when it was funded primarily through the sale of coltan on the black market. Piecing together the possible paths for this coltan, traded on the black market, was painstaking. The United Nations Security Council (UNSC) reports of the time were a major source of information as well as further research conducted by author Michael Nest. This detailed picture formed the life cycle part of the LCA-MRIOA, and would not have been possible if someone, somewhere had not done research and investigation on the ground. The international business community all denied using coltan from the DRC. The UNSC put people on the ground in the DRC to try to trace the possible exit points of coltan from the DRC, who was buying it and where it was going. The final supply chain paths used in the coltan study (chapters 4 and 5) were as much detective work as data collection and collation. If the study had been conducted without the use of the superior (detailed) data gathering through research, the results would have been very different. This is because the superior data both directed the upstream flow of the supply chains (filling in the gaps of where the coltan was being sold to, and accounting for black market trade) and allocated a social impact with the production of the product being traced (coltan). The novelty of this study was in the allocation of a social impact along an entire value chain, from production to consumption, and demonstration of how businesses can use MRIOA to trace production and supply paths for social impact accounting (see Chapters 4 and 5).

LOOKING BACK TO THE FUTURE

The use of quantitative analysis for social accounting led me to my next areas of research – economics and history. To better understand its applications and limitations, I delved into the history of IOA. Not having studied economics or history at a university level, both areas proved to be fascinating. Input-output tables were developed by Wassily Leontief to trace the flows of the economy (initially US) between sectors. There was a particular interest in the post-World War II economy and how spending would impact upon it (Leontief 1986). Leontief also showed that pollution could be considered as an input to production, which has led to the development of a significant body of work using environmentally extended input-output tables. The use of IOA for social accounting began in the 1950s (Burtle 1952, Peacock and Dosser 1957) and was strengthened in the 1960s by work by Richard Stone looking at national income in the post war years and concerns about employment and production (Stone, 1966). Social accounting research continued to develop, particularly with the use of Social Accounting Matrices (SAMS)

for the assessment of developing economies and associated social impacts (De Santis and Ozhan, 1997) (Dewhurst et al., 2011)(Pal et al., 2012)(Eckaus et al., 1981). However, with the rise of environmental concerns in the 1990s and early 2000s less focus was placed on social impact. This changed with the Global Financial Crisis in 2007 which brought about a new focus on the economy and how it linked with social progress. The report commissioned by the (then) French President Sarkozy into alternatives for the Gross Domestic Product (GDP) was the beginning of the wave to look for alternative measures of economic development and social progress (Stiglitz et al. 2009, Costanza et al. 2014). It is in this context that I looked at how to formalise the data collection and use of social-economic accounts (Chapter 3) and delved further into the history of social accounting (Chapter 2).

CONNECTING INFORMATION WITH ACTION

Armed with a better understanding of the history and economics behind social economic accounts, I began to consider how this research might be applied, and to what purpose. Through my career as I moved from environmental engineering to environmental management to sustainability management, I realised that although technology was vital, so too was engaging people. Technology can only go so far to reduce the environmental impact of an organisation. People also need to be engaged. Values, connectedness and data all play a part in environmental education (Johnson et al. 2012, Singh 2013, Krasny et al. 2010, Derevenskaia 2014). My work on sustainable palm oil has shown me that people care a lot about saving the animals and saving forests (McBain 2014), although the paths to take action are not always clear. Some people Tweet and use social media, some will donate to a cause, some consumers take action to lobby retailers and manufacturers, and some suppliers to change their procurement supply chain management practices for improved environmental outcomes. The difference between caring and taking action is significant.

The movement to improve the social outcomes of practices within supply chains has been patchy at best. On one hand some conditions have been improved through programs such as Fair Trade and the Ethical Trading Initiative. On the other hand, the International Labour Organisation[2] estimates that up to 21 million people worldwide are victims of forced labour, which generates US $150 billion profits in the private economy each year. One of the worst factory disasters in recent history occurred during the time I was writing this thesis. The collapse of the Rana Plaza in Bangladesh in 2012 shocked the world, killing 1138 textile workers and injuring more than 2000 others. The collapse resulted in the establishment of the *Accord on Fire and Building Safety in Bangladesh*[3], signed by more than 150 apparel corporations around the world. However, sales in the companies sourcing low cost and unsafe labour from the Rana Plaza were barely impacted. The Guardian newspaper reported that one apparel corporation that had been publically denounced after the collapse experienced a 20% growth in sales in the three months following the disaster (Neville 2013). The disconnect between information and purchasing practice of consumers is clear.

Why is there such a disconnect, and why are people more likely to advocate for change for the sake of animals or forests rather than other people? In themselves these are complex questions and I believe that part of the answer lies in quantification of the issues in question (deaths, injuries, income, schooling), and in another part in providing clear options for what can be done. The concept of environmental footprinting has been widely accepted and adopted by NGOs, consultants and consumers. The appeal is clear – an environmental footprint helps us to show the size of impact humans are having on the environment. If our impact is too great we will

[2] http://www.ilo.org/global/topics/forced-labour/lang--en/index.htm

[3] http://www.bangladeshaccord.org/

exceed the earth's carrying capacity. Van den Bergh and Grazi (van den Bergh and Grazi 2014) looked at the evolution of the ecological footprint as a concept and a methodology. Starting with the paper by Wackernagel and Rees (1996) and gaining momentum over the intervening years, they found that ecological footprints returned over 500 journal articles listed in ISI Web of Knowledge and 32 000 hits in Google Scholar. The simple quantification of impact is part of the powerful message delivered by an ecological footprint. As a concept, the idea that we are currently using two or three earth equivalents to live is powerful. But what of our social impact? What impact are our activities having on people? The limits are different, because humans are a renewable resource unlike some natural resources. However there are still limits within the system, such as the number of hours per day that a person has to spend (globally equal at 24) or basic requirements for life, such as proposed in Maslow's hierarchy of needs (Maslow 1943) including physiological needs (eg sleep, food) and safety needs (eg of employment, health). It is on this basis that to conclude my research I wanted to develop a methodology for a social footprint. The social footprint could be seen as an alternative to an environmental footprint, but used in a similar way to convey complex messages about social impacts of global trade (See Chapter 7).

STEPPING IN TO THE FUTURE

From my research I believe quantification, supported by qualitative data, has a role to play in helping us to engage on the subject of social impacts in the supply chain. Academically, the use of MRIOA to allocate social impact along a global supply chain had not been proven before I started this PhD. The traditional research fields for environmentally-extended MRIOA, such as industrial ecology and ecological economics, were not particularly interested in how MRIOA could be extended socially. Areas of social research (including conflict and peace studies) did not see the fit with a quantitative economic model. Sustainability accounting fields did not see this as part of their remit either. It took over two years and many rewrites and explanations to get the initial concept paper on the use of MRIOA to analyse social impacts in the supply chain (see Chapter 4) accepted to the *Journal of Industrial Ecology*, and the promise of a discussion on whether social footprinting even fits within the field of Industrial Ecology (see the Appendix for this commentary paper). This is surely part of the journey of breaking new ground. However, as a concept the idea has proven popular. An article was published in *New Matilda* (see the Appendix) on the subject, following an enthusiastic reception to a paper presented to a conference on environmental justice at Oxford University (see Chapter 5) and some wise advice from one of the conference organisers. This article was very well received and shared widely, with interest shown from areas as diverse as the public sector notices, a request for contribution to a radio script for the national broadcaster, to a reference within an article about funding of the arts[4].

It appears that the concept of associating a social impact from production to conception is engaging. Anecdotally, when discussing my research (on coltan in particular), people want to know if I can tell them how much impact they are responsible for. To date, attribution of social impacts to a product level has not been common. A study of the social life cycle assessment of a generic laptop computer reported that although the DRC is a country with 'severe impacts', the weight of material sourced for the production of a laptop was relatively low and thus the issue of ongoing conflict in the DRC linked with resource extraction was not strongly captured (Ekener-Petersen and Finnveden 2013; 139). With greater data certainty, this research shows that it would be possible to allocate the social impacts contained within production, along the supply chain to final end consumers.

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4 https://theconversation.com/is-there-any-clean-money-left-to-fund-the-arts-24159

This brings to question how consumption is dealt with by IO and MRIOA. To this end, Chapter 6 considers the application of IOA and MRIOA to understand consumption. Two previous works had addressed this question (Hertwich 2011, Wiedmann 2009) but did not take into account new developments in IOA such as the use of big data with MRIOA and cloud computing. Chapter 6 demonstrates that this area of study is being applied to a broader area of application than previously considered, ranging from environmental and social impacts, to international trade and global supply chains to policy development and assessment.

MRIOA should have a future in supporting the assessment of social impacts of supply chains in the future. This thesis makes an important contribution to our understanding of how social impacts can be analysed using MRIOA as a tool. What remains after this research are questions such as how the research can be applied to assist decision making in real world situations, where this field of research sits, and how better data can assist in modelling real life scenarios.

The following chapters of this thesis will show the evolution of accounting for social impacts (Chapter 2), trial the use of MRIOA to allocate social impacts at a country level through looking at how the data can be collected and analysed (Chapter 3), demonstrate by case study tracing a social impact through global supply chains (Chapters 4, 5), show how MRIOA has been applied and can be applied in the future (Chapter 6) and apply socially-extended MRIOA to develop a social footprint of trade (Chapter 7). Chapter 8 provides the conclusion to this thesis. There is inevitably some overlap between chapters, especially in the background sections, because each chapter, as a published article, needs to stand alone. I have reproduced the text here complete as it was either published or submitted. I would like to continue my work in the future as a science communicator, translating complex messages into something that an interested person could understand. The appendix picks up on this interest in communication, and provides a range of publications written for non-academic audiences on my studies and provides some context for how this information may be communicated in the future.

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CHAPTER 2: THE RISE AND RISE OF SOCIAL ACCOUNTING

ABSTRACT

Assessing, accounting for and reporting on social impacts have a long history. Most methods used today were developed to help us understand how production and employment would impact upon the post World War II economy.

Keywords: social accounting, social impacts, multi-region input-output analysis, social life-cycle assessment, GDP.

INTRODUCTION

Interest in social analysis, accounting for social impacts and reporting on progress has waxed and waned throughout history, in line with certain events that are usually global in nature and all pervasive. In January 2014 the charity Oxfam released a report on global inequality, attributing the richest 85 people in the world with holding as much wealth as the bottom half of the world's population (Fuentes-Nieva and Galasso 2014). At the World Economic Forum in Davos in January 2014 income disparity was highlighted as the greatest global risk over the next 10 years, keeping good company with other global risks including climate change and extreme weather, un- and underemployment, and cyber attacks. Economic inequality is ranked so highly because of its potential to impact upon social stability, health and societal wellbeing. In February 2014 Christine Lagarde, Managing Director of the International Monetary Fund (IMF) spoke about the global increase in inequality, stating that seven out of ten people live in a country where inequality has risen in the past three decades, and that in the US inequality has returned to levels not seen since before the Great Depression(Laguarde 2014). Lagarde also discusses gender inequality, and how by restricting women from participating fairly in economic activity everyone's living standards are reduced. Why have we become so much more interested and concerned about social impacts such as wage disparity, employment levels and gender inequality in the workplace? Why have the social statistics become front page news?

The short answer is probably the 2007 Global Financial Crisis.

What started with a bubble popping in the form of the collapse of the sub-prime mortgages in the housing market in the US quickly spread around the globe with a deafening sound wave as banks, financial institutions, businesses and even countries fell, leaving human collateral damage across the world.

The cost of this human collateral damage began to warrant some measurement. The impacts of poverty, unemployment, underemployment, age, gender, race diversity, health and wellbeing came into the economic focus. Even the IMF, represented by Christine Lagarde, has said that in the past economists have underestimated the importance of inequality, focussing on economic growth rather than economic distribution(Laguarde 2014). Increasingly, it seems like the golden geese of modern economic indicators, the Gross Domestic Product (GDP) and Gross National Product (GNP), are not producing the golden results that we once thought they were. Without taking social impacts into account, predictions based on GDP and GNP are looking more like fools gold.

THE GENERATION OF DATA

Hand in hand with the financial crisis came questioning of the validity of the GDP and GNP as measures of social analysis. Why were we using GDP and GNP to measure social outcomes in the first place? Following the end of World War II, a methodology was needed to work out how to pay for the war. This led to the development of the fields of social accounting based on economic data, to better understand social impact particularly as they related to employment, supply of labour, income distribution, equity and inflation(Burtle 1952, Peacock and Dosser 1957). The data underlying the formation of economic statistics such as GDP are collected in accordance with the System of National Accounts (SNA). The SNA is a framework to collect and present economic data in a format to enable analysis, policy development and decision making(United Nations Statistics Division 2009). First published in 1953, the SNA provides a system for measurement of wealth and the distribution of income, as it relates to the production and consumption of goods and services. (United Nations Statistics Division 2009) This was one

of the first attempts to take a systematic approach to measuring economic impacts and progress.

The SNA provided a structured approach to data collation and analysis within and across borders. However the SNA has some inherent flaws with respect to social accounting, particularly with respect to labour and gender. Writing in the 1980s Marylin Waring wrote one of the first feminist critiques of economics and in particular of the SNA. She found that there are inherent biases within national income accounting and the SNA, highlighting uneconomic growth and the gender bias because of the recognition of only paid work (Waring 1988). Unpaid household services have been estimated at up to 30 – 40% of the GNP (Stone 1986) so this is clearly a problem when reflecting the reality of life and society. Thus raising a child, maintaining a household or subsistence farming are not recognised in the national accounts, distorting income effects away from the impact of (primarily) women and all parts of society not involved with formal labour. Black market activity, cash-in-hand labour, bonded and slave labour are also overlooked by national accounting. The move from using GNP to GDP also masked unsustainable economic practices where in countries with significant foreign investment, such as in African states, GDP can be shown to have grown significantly over the past few decades whereas social impact measurement would indicate that individual income, equality and health have not followed the same path. As Robert Kennedy stated in 1968, GNP "*measures everything, in short, except that which makes life worthwhile*".[1] And yet somehow as a society we had forgotten that economic indicators are not social indicators.

So if the GDP and GNP don't measure health and wellbeing of a society, and were never designed to measure welfare, how do we analyse social impacts? In 2008 the then President of France, Nicholas Sarkozy, asked just that of economist Joseph Stiglitz and requested him to form the Commission on the Measurement of Economic Performance and Social Progress. The Commission brought together Amartya Sen and Jean-Paul Fitoussi, who along with Joseph Stiglitz and many others were to identify the limits of GDP as an indicator and consider how to develop more relevant indicators for societal progress over time and how they might be measured. Reporting in 2009, the Commission recognised the importance of having accurate data and statistics available on which to make decisions and policy choices (Stiglitz et al. 2009). This is particularly relevant given the information age in which we live and the immediacy of data availability, but we lack appropriate ways to analyse it, report it and understand the implications. The Commission found that GDP could hide worsening social conditions, well-being and inequality, if the aggregate per capita income is rising. To quote the Commission report, "*We are almost blind when the metrics on which action is based are ill-designed or when they are not well understood*." (Stiglitz et al. 2009; 9) Recognising that GDP was not designed to measure welfare, a means for quantifying societal and economic performance is lacking, particularly in a consistent and comparable method.

Alternative ways to account for social progress do exist, despite our love affair with GDP. Bhutan's Gross National Happiness (GNH) indicator has been around since the need was first identified by Fourth King of Bhutan in 1972. The GNH indicator covers psychological wellbeing, time use, community vitality, cultural diversity, ecological resilience, living standard, health, education and good governance, providing a significantly more well- rounded index for society than the GDP. For example, the GNH indicator measures labour in terms of working hours, including unpaid work (e.g. childcare), community work and voluntary work. An eight hour legal limit is applied to formal work, to calculate whether workers are overworked/time deprived.

[1] Address, University of Kansas, Lawrence, Kansas, March 18, 1968

Many other methods for assessing the progress of humans and society have developed over the past three decades. The Human Development Index has evolved from work beginning in the 1990s to measure three dimensions: life expectancy, education levels and the standard of living (based on income) and enables the comparison of time series data for individual countries, as well as comparisons between countries. The Gini Coefficient measures inequality based on income or wealth, with zero representing total equality and 100 representing total inequality. The Genuine Progress Indicator (GPI) is an alternative measure of GDP based on personal consumption expenditure and adjusted for social, environmental and economic impacts. A recent study of the GPI showed that, amongst other things, life satisfaction globally has not increased significantly since 1975 despite economic growth(Kubiszewski et al. 2013). Other indicators with a greater focus on individual prosperity include: the Organisation for Economic Co-operation and Development (OECD) Your Better Life index; the New Economics Foundation's National Accounts of Wellbeing and Happy Planet Index; and the Canadian Index of Wellbeing. Wellbeing indicators based on subjective wellbeing (Diener 2000) are plentiful, although their basis is more grounded in psychology, happiness and life satisfaction than economic wellbeing beyond the GDP. We clearly have ways to measure social impacts from a country basis, as well as an individual basis. So how do we measure social impacts being generated in the workplace?

THE SOCIAL IMPACTS OF WORK

Employment has a large role to play in the social structure of societies. The workplace can be a source of income, happiness, satisfaction and the producer of goods and services on which we all rely, but it can also be a source of death, injury and injustice. The collapse of Rana Plaza in Bangladesh in 2013, killing over 1000 workers in the textile industry is a chilling example of how work is not benign, and that businesses do not necessarily monitor their own acceptable social standards. Consumers are unlikely to say that they wanted cheap clothing so much that they were willing to have people die for them, and yet that is exactly what happened. Many businesses were unwilling or unable to respond appropriately, not only to ensure that safety standards in their supply chain were maintained but even to account for what happened in their supply chain. In 1992 the world was appalled when it first discovered that Nike and others were using child labour in their supply chain to stitch footballs, shoes and clothing(Nisen 2013). The fallout from this and other supply chain scandals contributed to the establishment of robust corporate social responsibility and sustainability programs.

Social accounting in various forms helps businesses and consumers tackle social impacts in supply chains. Two examples that take a global view are the Global Slavery Index and the Social Hotspot Database. Walk Free, the movement against modern slavery, works with governments, business and consumers to draw attention to the social ills that affect millions of workers worldwide. They are measuring and accounting for the social impacts of modern slavery through the Global Slavery Index which produced its first index in 2013. The Social Hotspot Database web portal, also released in 2013, similarly seeks to improve social conditions through providing an interface to quantify and account for social impacts in product supply chains(Benoit-Norris et al. 2012). These are two powerful examples of social data collection and analysis being made available to those with the power to make decisions.

Guidance abounds on how business, in particular, should assess and report on its social impacts. The Global Social Compliance Program (GSCP) was launched in 2006 to provide a business-driven programme for the continuous improvement of working and environmental conditions in global supply chains. In 2013 GSCP produced a Reference Tool on Social & Labour Management Systems for Suppliers, providing guidance on the assessment, planning and

reporting of social impacts within supply chains. Other advice covering the assessment of social impacts particularly as they relate to business and supply chains include the Global Reporting Initiative (GRI) G4 reporting guidelines (also released in 2013), the International Standards Organisation (ISO) ISO 26000 guidelines on Social Responsibility, Social Accountability SA8000 standard, the UN Global Compact and the OECD Guidelines for Multinational Enterprises. Certification systems also provide strong guidance on measuring and accounting for social (and environmental) impacts in supply chains, include well identified labels such as Fair Trade (whose certification labels are well known on tea, coffee and chocolate), the Forestry Stewardship Council approved (whose labels can be recognised on timber products) and the Marine Stewardship Council approved (whose labels identify sustainably sourced seafood).

The guidance generally fails when it comes to providing robust methodologies for assessing social impacts quantitatively. In the mid-2000s the idea of a quantitative social footprint for business was beginning to emerge(McElroy et al. 2008, Norris 2006), but few methodologies had the capability to calculate such a thing. Multi-Regional Input-Output (MRIO) analysis, a methodology using datasets based on the SNA, was not even available until around 2008 because of the computational power required to map the global economy (Kanemoto and Murray 2013). However, as analysis becomes more sophisticated the MRIO analysis methodology enables supply chains and social impacts to be traced across countries and economies and can be used to calculate social, carbon and environmental footprints. Examples of accounting for social impacts are now emerging using this methodology (Alsamawi et al. 2014, McBain and Alsamawi 2014). MRIO analysis has often been used in conjunction with Life Cycle Assessment (LCA) to provide a bottom up/top down method for data analysis(Wiedmann et al. 2011, Lenzen 2002, Feng et al. 2011, Suh and Nakamura 2007).

In 2005 there was enough interest in social impacts in LCA for the United Nations Environment Programme/Society of Environmental Toxicology and Chemistry (UNEP/SETAC) Life Cycle Initiative to establish a working group on social impacts. In 2009 the Guidelines for Social Life Cycle Assessment of Products were released, followed by Methodological Sheets for the Subcategories of Social LCA in 2013, providing information on data assessment for inventory analysis for social LCA(Benoit-Norris et al. 2011). The Social Return on Investment model was developed in the early 2000s, leading to the formation of a global network of practitioners and a model for accounting for social impacts. The Social Return on Investment methodology provides a way to measure and communicate non-financial value (such as social impacts) for projects or organisations, and several tools have evolved to help users calculate SROI. Cost benefit analysis and responsible investment also sit within this field.

There is clearly a developing interest in social analysis, accounting and reporting, and the pressure is coming from many different directions. Legislation is pushing business and government down the path to considering social impacts and how to account for them. As part of the financial reforms in the USA, Section 1520 of the Dodd-Frank Act 2010 requires listed companies to report publicly on the source of conflict minerals (tin, tungsten, tantalum and gold), and if the source is the Democratic Republic of Congo further demonstration that the sourced material is conflict free is required(Strickland 2011). The UK Public Services (Social Value) Act 2012 is a demonstration of the increasing emphasis being placed on formally measuring and monitoring social impacts and outcomes for government expenditure. The Act places a duty of care to consider social value on those who commission or procure services, some forms of goods and the delivery of works. Social value is neither defined by the Act nor is guidance provided on how to measure it, emphasising the need for a greater understanding of social accounting.

THE ROLE OF INFORMATION

Our demands for information on societal progress and social impacts are changing, particularly as our neighbourhood expands from a once small area to be traversed on foot to the now global community of the information age. Connectivity is another key reason why social accounting is on the rise. From the first public mobile phone call made in New York in 1973, mobile telephony has expanded to include approximately 6.8 billion mobile phone service subscribers worldwide for a global population of just over 7.1 billion people. In countries as diverse as Russia, Italy, Iran, the Philippines, Colombia, South Africa, Australia and the UK there are more mobile phone subscriptions than people. Mobile phones are revolutionising communication and the way people interact. Africa has one of the fastest growing rates of mobile phone penetration in the world. Some of the social impacts associated with this connectivity revolution include poverty reduction, access to agricultural information, banking, clean water and education. In some African countries more people have access to a mobile phone than access to clean water or electricity(Africa. and Bank. 2013). The ability to run mobile devices and smartphones relatively cheaply off mobile broadband networks that require little infrastructure can help people become connected global citizens. As demonstrated with the uprisings in the Arab Spring, connectivity and global citizenship can be powerful forces for justice and social awareness. Inequality, poverty, lack of opportunity and empowerment are amongst the social issues demanding to be addressed. As such our need for information on social impacts grows, and we find ourselves needing new ways to analyse, account for and report on the global society in which we live.

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CHAPTER 3: QUANTITATIVE ACCOUNTING FOR SOCIAL ECONOMIC INDICATORS

ABSTRACT

In this paper we consider the evolution of quantitative accounting of social indicators for measuring societal progress and sustainable development, with particular reference to economic analysis and social indicators. We examine the use of the System of National Accounts and introduce the concept of using input-output analysis for the development of social indicators. The use of satellite accounts for input-output analysis of environmental impacts and the development of environmental footprints has been well documented. The novelty of this paper is the use of a methodology frequently used to develop environmental indicators to quantify social impacts and to further the development of social footprints. We provide a case study of the use of social satellite accounts for labour, using multi-regional input-output analysis to develop a global inequality footprint for labour embodied in trade, and argue the case for the development of a system of social economic accounts, similar to the System of Environmental-Economic Accounts adopted by the United Nations Statistical Commission in 2012. This work contributes to the development of social valuation metrics as a means for measuring societal progress and developing sustainability indicators for use in management and decision-making.

Keywords: Social footprint; social accounting; multi-regional input-output analysis; social indicators; inequality; sustainability indicators.

INTRODUCTION

There is an increasing interest in quantitatively measuring sustainability and wellbeing beyond economic indicators. The use of Gross Domestic Product (GDP), Gross National Product (GNP) and Gross National Income (GNI) to measure economic progress is well established. The data underlying these calculations are collected in accordance with the System of National Accounts (SNA), an accounting framework that allows economic data to be presented in a format that enables analysis, policy development and decision making (United Nations Statistics Division 2009). Although useful as a tool for economic analysis, there is increasing concern over the validity of using GDP or GNP to assess social progress. As Robert Kennedy stated in 1968, GNP "*measures everything, in short, except that which makes life worthwhile*".[1]

There is increasing dissatisfaction with the use of economic statistics alone to measure social performance — but a lack of agreement as to whether a suitable alternative should be sought or whether to use the robust guidelines for data collection within the System of National Accounts (SNA). In 2008, the then President of France, Nicholas Sarkozy, asked the economist Joseph Stiglitz to form the Commission on the Measurement of Economic Performance and Social Progress whose aims were to identify the limits of GDP as an indicator, to consider how to develop more relevant indicators for societal progress over time, and to determine how they might be measured. The Commission reported in 2009, recognising the importance to have accessible and accurate data and statistics available on which to base decisions and policy choices (Stiglitz et al. 2009). The report refers to the System of Environmental-Economic Accounting (SEEA) as a means to extend the SNA to cover environmental impacts, although it recognises that measuring environmental degradation and ex-post accounting poses its own difficulties (Stiglitz et al. 2009). Further discussion is given to valuing human capital within the SNA framework, particularly with respect to developing a system of household production, while recognising the challenges of changing the existing system (*Ibid*.:104). Recognising that the SNA does not cover many social impacts and that it was not designed to measure welfare, a means for measuring societal progress and economic performance as social or sustainability indicators is lacking, particularly in a consistent and comparable method.

A plethora of indicators now exist to measure well-being and environmental performance. However, there is no accepted methodology for the collection of social data and its development into indices. The SNA was not developed to assess all possible indicators of progress, and the use of satellite indicators is evolving to enable the calculation and comprehension of primarily the environmental impacts that lie beyond the GDP. In section 2 of this paper, we consider the evolution of social indicators from post-war development of the SNA to business social impact measurement, as well as the drivers for their development. In section 3, we then consider the use of satellite accounts to input-output (IO) matrices that contain social data and their use for analysing social impacts, particularly in terms of multi-regional analysis. In section 4, the case study of associating labour statistics with a multi-regional input-output table is used as an example of how input-output analysis can be extended to include social impacts. Sections 5 and 6 conclude, with a discussion of some future uses for this type of data analysis and a consideration of the benefits of developing a System of Socio-Economic Accounting (SSEA) to encourage the comparison of societal statistics with economic data and to provide a more robust view of societal progress. (Beyond GDP) (Beyond GDP) (Beyond GDP) (Beyond GDP) This work contributes to the development of social valuation metrics based on environmental and economic accounting as a means for measuring societal progress, sustainable development and developing indicators for use in management and decision-making.

[1] Address, University of Kansas, Lawrence, Kansas, March 18, 1968.

THE EVOLUTION OF SOCIAL INDICATORS

In the 1950s IO analysis was a new field, and there was significant interest in using IO analysis to better understand social impacts. For example, Burtle (1952) wrote about the use of IO analysis for developing policies on manpower supply and full employment. Peacock and Dosser (1957a) used IO analysis in an underdeveloped country to analyse income distribution, equity and inflation.

Richard Stone began writing about social accounting using IO analysis in the 1950s. He found that in the post-World War II economy there was not much emphasis placed on the difference between national capital and national income, but that statistical analysis was skewed towards national income. He attributed this focus on national income to concerns regarding employment and production in the post-war years but found that it led to incomplete data being used for analysis in national statistics (Stone 1966). In response to US research into the condition of American society, Olson Jr (1969) suggested that social statistics be developed into a set of "policy accounts" to encourage cost-benefit analysis and better understanding of the relationship between social expenditures and the social indicators that they were affecting. Olson Jr raised the point that social indicators should fit within a systematic scheme of classification.

After developing the concept of a Social Accounting Matrix using input-output tables, Stone went on to develop the Cambridge Growth Model and the first social accounting matrix (SAM) for Great Britain in 1960 (Stahmer 2004). Since then, social accounting matrices have regularly been constructed by region or country, primarily for use in policy decision-making. Examples include: Turkey (De Santis and Ozhan 1997), Libya (Dewhurst et al. 2011), India (Pal et al. 2012) and Egypt (Eckaus et al. 1981). SAMs have been used to look at the impact of particular industries in a country, such as fishing in Alaska (Seung and Waters 2009) or tourism in Mozambique (Jones 2010) and for economic analysis (Santos 2004). SAMs have also been used for assessing environmental impacts by using environmental satellite accounts within a SAM (Cardenete et al. 2012; Morilla et al. 2007; Xie 2000). Others have used a SAM for considering social inequality (Sanz and Perdiz 2003) and trickle-up redistributive cycles that perpetuate poverty (Lenzen and Schaeffer 2004). However the use of SAMs remained primarily a governmental or policy information tool. Since the development of the methodology of SAMS, work on the improvement of social statistics and their integration with demographic and economic statistics was carried out by the United Nations Statistics Office in the late 1970s and early 1980s (Stone 1986) although in the years following this literature, the measurement of social indicators declined in preference to environmental indicators.

In the 1990s, as the dominance of business in society became apparent, it began to emerge that business lacked a methodology or process for measuring and reporting on social progress. In 1997, the Global Reporting Initiative (GRI) was formed, as a collaboration between the Coalition for Environmentally Responsible Economies (CERES) and the Tellus Institute, which by 2002 had become an independent not-for-profit organisation collaborating with the United Nations Environment Program (UNEP). The GRI published their first full Sustainability Reporting Guidelines in 2000 (Global Reporting Initiative 2013) which provide organisations with a framework to report on the environmental, social and economic aspects of their day-to-day operations. The guidelines provide a systematic approach for reporting against social indicators, while allowing for flexibility in the reporting organisation (Global Reporting Initiative 2013). Many comments have been made on the reliability and thoroughness of using GRI indicators, particularly to define social impacts. Liam *et al* (2013) recommended a top down (using established indicator frameworks) and bottom up (responsive to community expectations) approach to reporting on social sustainability. There is also agreement that sustainability

reporting against guidelines such as the GRI can actually obfuscate performance or use reporting to legitimise non-sustainable performance (Aras and Crowther 2009; Faisal et al. 2012; Graham 2010; Owen 2006; Young 2011) and thus does not provide a better understanding of social progress.

Around the time of the establishment of the GRI, John Elkington proposed that an alternative to traditional financial reporting was required for businesses, and proposed the triple bottom line — reporting against financial, social and environmental performance (Elkington 1998). Yongvanich and Guthrie (2006) identify that systems for social reporting are less developed than those for environmental reporting, and that more robust systems are required. Parker (2005) found that for the field of social and environmental accounting the literature has been dominated by environmental accounting since the late 1980s, with a declining emphasis on social accounting. Of the social accounting that exists for businesses, there is a plethora of methodologies and underlying theories, yet data quality is variable and the outcomes of the reporting are often aligned to specifically desired corporate outcomes (Parker 2005). McElroy *et al* (2008) also argued that sustainability reporting failed to make businesses accurately assess their sustainability impacts and suggested the use of ecological and social quotients as well as a form of measuring and reporting on the social sustainability of an organisation in the form of a social footprint. Considering this range of views, from a business perspective a standard approach to quantitative accounting for social indicators could be of great benefit.

As indicated in the introduction to this paper, many multidimensional social indicators in the form of well-being indicators have emerged following the Global Financial Crisis of 2007. There was recognition of the need for indicators that measure societal progress beyond GDP, and for government to regulate businesses and work with society to improve societal outcomes. Composite social indicators have existed for many years. One of the first alternatives to the GDP recognised by a State is Bhutan's Gross National Happiness (GNH) indicator. The early origins were as a conceptual measure, suggested by Forth King of Bhutan in 1972; in the most recent survey (2012) the GNH indicator covers nine domains (psychological wellbeing, time use, community vitality, cultural diversity, ecological resilience, living standard, health, education, good governance) made up of 124 variables (Ura et al. 2012). For example, the GNH indicator measures labour in terms of working hours, including unpaid work (e.g. childcare), community work and voluntary work. An eight hour legal limit is applied to formal work, to calculate whether workers are overworked/time deprived (Ura et al. 2012).

Another important social indicator is the Human Development Index (HDI). Launched in 1990, the Human Development Reports were created to go beyond national income assessment and to focus on human well-being (United Nations Development Program, 2013). Combining the works of Mahbub ul Haq and Amartya Sen, the Human Development Reports were expanded to include policy issues such as sustainable development, gender equality, poverty, human rights and sustainable consumption as well as the introduction of the HDI (Fukuda-Parr 2003). From 2011 the HDI has measured three dimensions: life expectancy, education levels and the standard of living (based on income) (United Nations Development Program 2013). In each year, some countries are not included in the HDI, primarily because of the unavailability of crucial data. The Gini Coefficient is a measure of one aspect of social indices, which gauges inequality based on income or wealth with 0 representing equality and 100 representing total inequality. A recent study by Kubiszewski *et al* (2013) compared the Genuine Progress Indicator (GPI), an alternative measure of GDP based on Personal Consumption Expenditure adjusted for 24 socio/environmental/economic impacts, with other indicators such as GDP, HDI and the Gini Coefficient over time to calculate that, among other things, life satisfaction globally has not increased significantly since 1975. Other composite social indicators combining economic with social and environmental data include: the Organisation for Economic Co-operation and

Development (OECD) Your Better Life Index, which tracks progress across 11 dimensions for member countries; the New Economics Foundation's National Accounts of Wellbeing and Happy Planet Index; the Canadian Index of Wellbeing; as well as many other indexes specific to individual countries and organisations. A summary of well-being indicators can be found in Smith *et al* (2013). Well-being indicators based on subjective well-being as defined by Diener (2000) are plentiful, although they are based more on psychology, happiness and life satisfaction than on economic well-being beyond the GDP.

These indicators have specific and varying methodologies for calculation and sourcing input data. The main focus of output for these composite social indicators is policy development, particularly by the government sector. This is certainly true of the HDI, although various corporate uses have been found, such as for differential pricing structures (Wolff et al. 2011). However, the need developed to aid business to better understand their social impact, particularly around trade and consumption. This is at a time when the annual revenue of multinational enterprises is greater than the GDP of many countries. For example, Trivett compared the turnover of major US firms and found that the top 25 US firms turnover exceeded the economies of over 125 countries' GDPs, including Norway, Thailand and New Zealand (Trivett 2011). The lack of consistency and reliability of datasets is also an issue, as highlighted by Ranis and Stewart (2012) when considering societal progress as measured by the HDI. Wolff *et al* (2011) also found that significant errors occur in the calculation of the HDI due to data error, and that the higher the development status of a country the higher the accuracy of the underlying data used. Stone (1986) also identified data collection and consistency of data to be a problem when assessing social accounts. Unlike triple bottom line reporting or the use of well-being indicators, a standard methodology for constructing input-output models and social accounting matrices exists within the System of National Accounts (SNA).

SOCIAL INDICATORS AND THE USE OF INPUT-OUTPUT ANALYSIS

As part of measuring the interactions of the economy, the SNA allows for measures of wealth and distribution of income, as the latter relates to the production and consumption of goods and services (United Nations Statistics Division 2009). The SNA also enables international comparisons of economic data across countries throughout the world. Statistics and data collected in accordance with the SNA include production, distribution of income, redistribution of income, household expenditure, capital account, a balance sheet of assets and liabilities as well as the external transactions account or balance of payments. First published in 1953, and most recently updated in 2008, the SNA provides an internationally agreed standard for compiling economic statistics (United Nations Statistics Division 2008), which form the basis for the development of input-output tables.

Chapter 28 of SNA 2008 outlines the presentation of supply and use tables in a matrix form, to be used as either input-output tables or as social accounting matrices (United Nations Statistics Division 2008). The main differences between a SAM and I-O models are in the flows — an IO model looks at the flows of money between producers, whereas a SAM looks at the flows of money between producers and the interdependence of production with the rest of society (Martinez de Anguita and Wagner 2010).

Developed by Statistics Netherlands, the National Accounting Matrix including Environmental Accounts (NAMEA) allows for the consideration of satellite environmental accounts to a SAM. Limited use is made of social accounting in a NAMEA, such as the estimation of national income in an ecologically sustainable society or an income distribution and use account, which does not appear in the System of Environmental Economic Accounting (deHaan and Keuning 1996). The

European System of Accounts (ESA) contains guidance on the use and applications of SAMs, including the compensation to employees with possible breakdown of statistics into resident/non-resident, sex, occupation and even level of schooling, age, type of work (e.g., full time/part time) and average wage (Stahmer 2004). More closely linked to understanding social indicators is the SAMIO — a social accounting matrix with IO analysis. A SAMIO can group sections of the population, for example by age, households or education levels. Yet none of these systems addresses the full extent of social accounting, particularly as it relates to work.

IO analysis, the economic modelling first described by Wassily Leontief, allows the computation and understanding of the relationships between the inputs and outputs of each sector of an economy to other sectors, giving a view of the entire economy (Murray and Wood 2010). Leontief envisaged that input-output analysis, including multi-regional analysis and dynamic analysis, could be used to quantitatively assess the external effects (desirable or undesirable) resulting from consumption and production, including the problems of negative environmental impacts, labour and uncontrolled economic growth (Leontief 1970). Stone identified that using satellite accounts could introduce additional information to national accounting, covering issues such as health, education and alcoholism, and could bring monetary and non-monetary data into the central national accounting system (Stone 1986).

When considering the SNA from a social accounting perspective, particularly with respect to labour, there has always been a part of the picture lacking. Writing in the 1980s, Marylin Waring found inherent biases within national income accounting and the SNA, highlighting uneconomic growth and the gender bias inherent in the statics due to the recognition of only paid work (Waring 1988). Unpaid household services have been estimated at up to 30-40% of the GNP (Stone 1986). Chapter 19 of SNA 2008 states that "All individuals that make up households (the population) are only identified insofar as they engage in consumption expenditure" (United Nations Statistics Division 2009). Some of the issues regarding unpaid labour raised by those such as Waring have subsequently been addressed in revisions of the SNA. However, the SNA's system to account for labour and associated social impacts is clearly not fully developed, and the addition of satellite social accounts could work to address this imbalance.

The value of multi-regional input-output (MRIO) analysis to assess environmental impacts across country borders has been previously established. However, linking social externalities with a MRIO database through the use of satellite accounts is still relatively rare. Using this methodology, social impacts such as labour, working hours, social conditions, employment or health can all be modelled and assessed. Abbas used input-output analysis to link high employment to the employment generators in specific industries (Abbas 2003). IO analysis has been used to look at income distribution (Albert and Mònica 2012), for socio-economic forecasting (Kim and Hewings 2012), to map population risks (Ma et al. 2012) and for corporate benchmarking (Matthews and Lester 2003) Input-output analysis has also been used for policy design (Baumol and Wolff 1994; De Miguel-Velez and Perez-Mayo 2010). Some examples of using IO analysis for socio-economic analysis include: tourism (Fletcher 1989; Los and Steenge 2010); specific sector contributions to the national economy, such as construction (Acquaye and Duffy 2010; Huang and Bohne 2012; Kofoworola and Gheewala 2008; Selin 2011) and consumption and waste (Dietzenbacher 2005; Kerkhof et al. 2009; Nakamura and Kondo 2002; Xu and Zhang 2009). There is also a significant history of using satellite accounts for tracking carbon emissions and ecological footprinting or environmentally extended input-output analysis (Bin and Ang 2013; Du et al. 2011; Su and Ang 2011; Wiedmann et al. 2006) to the extent that the System of Environmental-Economic Accounts has been established by the United Nations Statistical Commission. However, specific-use social accounts for IO analysis are relatively rare, yet can provide a useful tool for policy analysis and development as well as supply chain analysis by business and consumers.

CASE STUDY: SOCIAL INEQUALITY FOOTPRINT

The use of MRIO analysis to calculate environmental footprints has been well documented (Miller and Blair 2009; Murray and Lenzen 2013b; Turner et al. 2007). Satellite accounts have been used to enumerate environmental issues which are not addressed through standard national accounting. Examples of global environmental footprints calculated using the MRIO methodology with satellite accounts include carbon footprints (Hertwich and Peters 2009), water footprints (Feng et al. 2011a) and biodiversity footprints (Lenzen M et al. 2012ba).

Using the same methodology used for environmental footprinting outlined above, social satellite accounts can be used with MRIO databases to calculate social footprints. In this case study, we calculated a global inequality footprint of labour embodied in trade, covering 187 countries throughout the world for the year 2010. The Eora MRIO database[2] was used as the basis for this study (Lenzen et al. 2012bb; Lenzen et al. 2013b). The satellite accounts were developed using data on employment, income and the Gini indices to construct income distributions. When used together, the MRIO data and income distribution satellite account enabled tracing economic activity in one location to income distributions in other locations around the world. Employment data were taken from the International Labour Organization's LABORSTA database (ILO 2012), and the United Nations System of National Accounts official country database (UNSD 2011). The Standardized World Income Inequality Database (SWIID) version 3.1 (Solt 2009) and the OECD database provided Gini indices referring to both before-tax and after-tax income. In this paper we have used the after-tax Gini index data. We also relied on information from the Gini index database from the World Bank. In order to construct an inequality footprint we first devised a strategy to estimate distributions of income using three data items: (1) the country's Gini index, (2) the total salary payments for employees, and (3) the total workforce of the economy. We then combined the distributions of income results with employment data to construct two satellite accounts, employment ($\mathbf{Q}_{\mathbf{emp}}$) and income ($\mathbf{Q}_{\mathbf{inc}}$).

To extend MRIO analysis to include social issues, we employed IO analysis to highlight embodied labour and embodied income payments. To do this, we combined the input-output system (where $\mathbf{T}$ is intermediate transactions matrix, $\mathbf{v}$ is value-added matrix, and $\mathbf{y}$ is final demand matrix) with the data of the two satellite accounts $\mathbf{Q}_{\mathbf{emp}}$ and $\mathbf{Q}_{\mathbf{inc}}$. The methodology is exactly the same as that used in the ubiquitous carbon footprint studies, i.e. an economic multi-region IO table, a physical satellite, in this case income percentiles, and Leontief's demand-pull impact calculation.

By applying the Leontief Inverse calculation to the MRIO table with associated satellite accounts, the resulting data shows the employment and wages footprints for every nation's consumption broken down into contributions from the populations of 187 countries covering the output of 14,787 economic sectors. The footprints show how much employment and wages are required within a country and how much is imported from other countries, to satisfy its consumption of products and services. For a more detailed explanation of the methodology, see Alsamawi *et al* (2014a).

An inequality footprint can provide a tool to assist in tracking the inequality (as measured by the Gini index) of the workforce required to produce goods and services as they are traded around the world. In essence this case study shows the "embodied labour" within export goods. Inequality in terms of income disparity is being addressed by national Governments, global organisations, non-government organisations and the business world. In its 2012 report, the

[2] www.worldmrio.com

World Economic Forum identified chronic fiscal imbalances and severe income disparity as two of the highest ranking global risks (World Economic Forum 2012). By using MRIO analysis with social accounts, we are able to consider the problem from a whole supply chain perspective of labour, as opposed to just what is happening in each country. Individual product life cycle assessments tend to look at an the individual supply chain but have difficulty covering all stages of production and consumption across multiple economies (Kanemoto and Murray 2013). Labour condition auditing focuses on individual factories or sites within a supply chain; whereas providing detailed qualitative information does not provide extensive whole of supply chain quantitative information (Kortelainen 2008) MRIO analysis, with specific satellite accounts for social impacts, can enable full supply chain analysis. With the addition of further satellite accounts, this inequality footprint could also take into account gender, wage, age and sector inequalities, as well as intra and inter-country inequality.

Our results showed that more than 20% of the world's employed work for consumption in a country other than their own. About 50% of those people (or approximately 10% of the world's workforce) worked for only eight countries (see Figure 1). Of the top eight countries identified, China is clearly the world's greatest exporter, being the primary exporter to seven of the eight identified countries. We can see by comparison that the aggregate income received by Chinese workers is quite high, when compared to workers in Madagascar or the Philippines. If we consider the case of Madagascar, a key exporter of labour to France, it takes approximately 1 million full time equivalent (FTE) people employed to generate US$ 100 million of income (a wage of approximately US$ 100/person/year). By comparison with Spain as an exporter of labour to France, a similar number of employees — almost 1 million FTEs — employed generated an income of US$ 13 billion (a wage of approximately US$ 13,000 per person per year).

The calculations behind the inequality footprint can also reveal the commodities being traded, through structural path analysis (Lenzen 2006a). By looking at Table 1 we can see the commodities being exported in the trade between countries shown in Figure 1. As we can see from Table 1, China is a strong exporter of information and communications technology goods as well as clothes; Russia is an exporter of mining products; and Madagascar is an exporter of agricultural products. We can see from this that the goods produced obviously have an impact on the income received. Countries such as Madagascar, exporting agricultural products, including crustaceans, fruit and vegetables, are likely to have a lower income per capita than countries such as Germany exporting medical equipment, cars and gold.

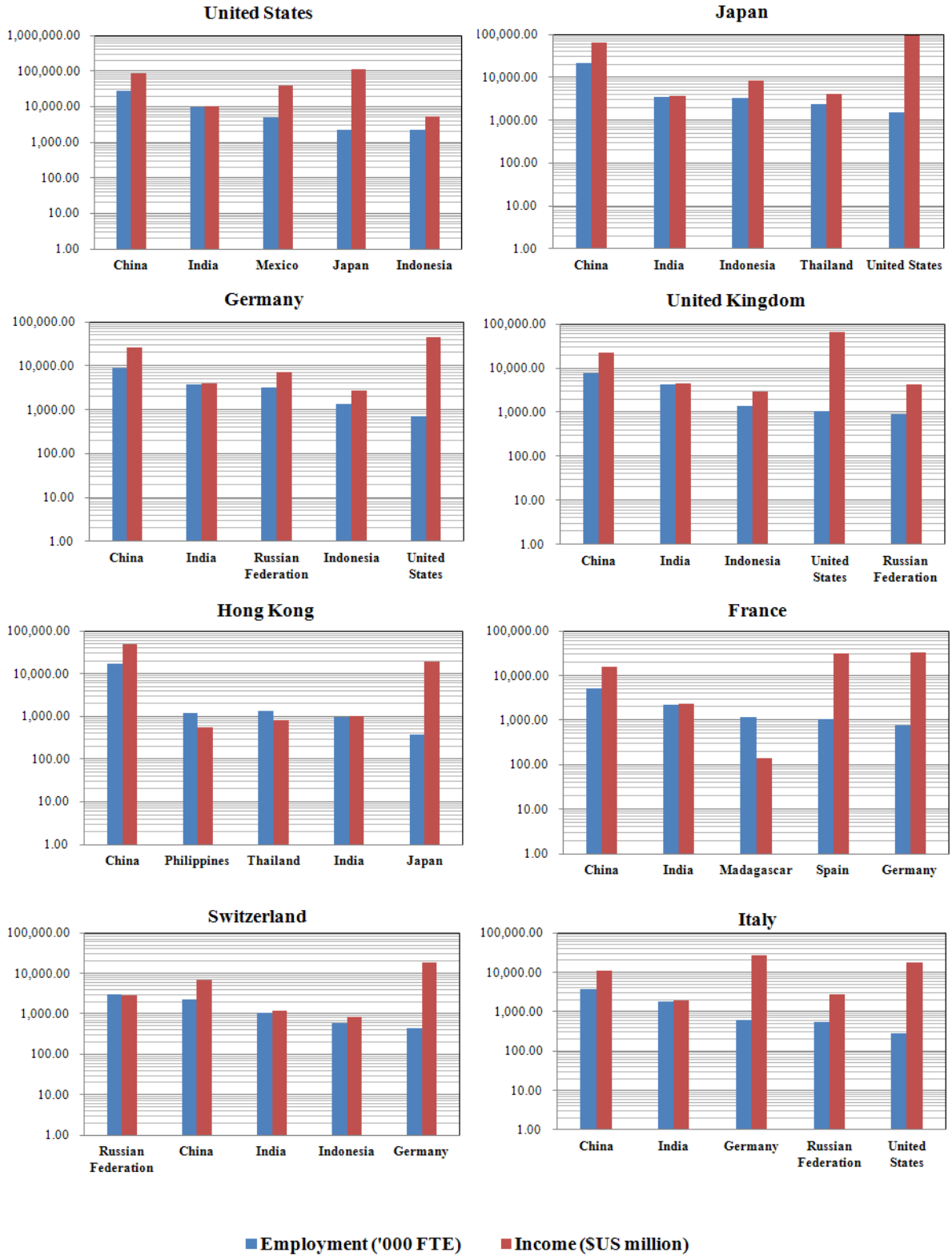

Figure 1. Inequality footprint and embodied labour: The world's top 8 inequality implicated importers and their supplier countries.

Source: Alsamawi et al 2014 and the Eora MRIO database

Table 1. Inequality implicated commodities by import market

Import country	Inequality-implicated commodities and their exporting country
United States	CHN com, tel, mp, clo; IND, diamonds, clo, med; MEX mp, cars, accars, po; IDN clo, rub, po; JPN cars, accars, printers;
Japan	CHN com, mp, clo, trans; IDN pg, gold, po, coal; IND po, fer, diamonds; PHL eic, diodes, ban; USA jets, med, maize, eic;
Germany	CHN com, diodes, clo, cruise; IND clo, med, diodes, trans; RUS cop, po, coal; IDN palm oil, rub, clo; USA cars, eic, med;
United Kingdom	CHN com, trans, tel, clo; IND clo, med, po; USA gold, jets, med; RUS po, coal; IDN clo, palm oil;
Hong Kong	CHN tel, eic, com; PHL eic, diodes, com, gold; THA eic, com, gold, diamonds; IND diamonds, jew, cotton yarrn; JPN eic, diodes;
France	CHN com, trans, clo; IND po, clo, med; MGD crust, clo, vegetables, fruits; ESP cars, accars, tracks, med; DEU cars, med;
Switzerland	RUS cop, plat, prec; CHN com, tel, clo; IND oxy, clo; IDN fer, clo, chem; DEU med, cars, gold;
Italy	CHN com, diodes, clo; IND po, clo, diodes; DEU cars, diodes, med; RUS pog; USA med, jets;

***Note*: Country abbreviations: BRA:** Brazil. **CHN:** China. **DEU:** Germany. **ESP:** Spain. **IDN:** Indonesia. **IND:** India. **JPN:** Japan. **MEX:** Mexico. **MGD:** Madagascar. **PHL:** Philippines. **RUS:** Russia. **THA:** Thailand. **USA:** United States of America.

Commodity abbreviations: accars: part and accessories of cars and motor vehicles. **ban:** banana and plantains. **chem:** chemical and allied products. **clo:** clothes and textile products. **com:** automatic data processing machine. **cop:** copper. **crust:** crustaceans. **eic:** electronic integrated circuit. **fer:** ferrous products. **jew:** jewellery. **jets:** turbojets. **med:** medicines **mp:** monitors and projectors. **oxy:** oxygen function amino compounds. **pg:** petroleum gases. **plat:** platinum. **po:** petroleum oil. **pog:** petroleum oil and gas. **prec:** precious metal ore. **rub:** natural rubber. **tel:** telephone. **trans:** transmission apparatus for radio and TV.

Source: Alsamawi et al, 2014 and The Observatory of Economic Complexity, (2012). Internet site http://atlas.media.mit.edu/ , (USA: MIT).

In their report, Stigliz *et al* (2009) recognised that large changes in societal inequality are often not reflected in traditional measures of progress, such as the GDP. Due to the per capita measure, an increase in the overall average income of a nation can occur at the same time as an increase in people who are worse off than before. This case study highlights how we can use social satellite accounts with MRIO to consider social inequality and trade.

Leontif believed in the use of IO analysis to help with social policy related economic decisions, such as national employment and job sector movement, taxes, growth, health and education (Leontief 1985). He stated in an interview in 1985 that "…introducing modern technology will ultimately reduce very markedly the role of labour as an input in all production processes, just as tractors reduced the role of horses in agriculture. This causes all kinds of problems — income distribution for one, because if you don't need horses in production you just eliminate them. It will not be so easy to eliminate humans … I argue that in a not so remote future, we will have quite enough output to feed the entire American population even if we work only thirty hours a week." (Leontief 1985). Labour inequality, in terms of hours worked, conditions and income are still important issues almost two decades later, and the use of social satellite accounts to IO analysis can help quantify and better understand the issues.

DISCUSSION

Interest in understanding the social or human aspects of economic measurement is increasing. As outlined previously, there is an increasing number of well-being indicators, in response to calls for indicators that measure more than GDP and recognize the limitations of the SNA to measure social impacts. As argued by deHaan and Keuning (1996) the SNA provides a framework for understanding some aspects of welfare such as net national income, employment and government social payments but does not provide a framework for the development of a complete picture of the social state of society. A limited range of social issues is addressed in SNA93, through reference to economic flows such as social insurance schemes, population and labor inputs, informal aspects of the economy, social accounting matrices, satellite accounts and other extensions. SNA 2008 recognizes that welfare is a difficult concept to capture within a system that is not designed to do so. It explores the possibility that unpaid services and environmental impacts could be considered by expanding the SNA structure, but that most aspects of welfare will remain outside of the SNA system (SNA 2008:13).

The case study above demonstrates that there is scope to use IO, based on the SNA, to develop social indicators and enumerate social issues. In response to the calls for economic measures beyond the GDP, an additional set of guidelines covering social accounting should be developed. In 2012, the United Nations Statistical Commission adopted the SEEA as the international standard. The SEEA has the same status as the SNA, and is considered to be a satellite system of the SNA allowing for the comparison of environmental statistics with economic data. Just as environmental accounting is part of the SNA and also a standalone system with the SEEA, so too could social accounting be included in the SNA chapter on satellite accounts and other extensions but also developed as a standalone system. The SEEA provides "a statistical framework consisting of a comprehensive set of tables and accounts, which guides the compilation of consistent and comparable statistics and indicators for policymaking, analysis and research.":(Division 2014) A System of Socio-Economic Accounting could similarly provide a framework for economic and social information to enable a consistent analysis of society's impact on the economy, or the economy's impact on society. A SSEA could provide an avenue to address shortcomings of the SNA, including accounting for unpaid, voluntary or black market labor. A system could also outline how to establish and use satellite accounts to address issues such as wage, gender, industry and country inequalities as highlighted in the case study. Given

the case study provided, a system and its analysis could be of use not only for governments and non-governmental organizations for policy development, but also for businesses when quantifying their social impacts and looking at a time series approach. Just as for SEEA, a global consultation process could guide the development of a SSEA and the social indicators to be addressed.

CONCLUSION

There are many uses and applications for social indicators, but no accepted standard means for gathering and comparing data. Increasing recognition of the need for more thorough examination of economic data for indicators of sustainability and societal progress suggests that new systems of analysis are required. The evolution of social indicators shows that they have been developed for many outcomes, from paying for a world war to accounting for business sustainability. The development of social metrics, particularly for indicator based assessment, has lagged behind the development of environmental metrics. This gap raises uncertainty of how triple bottom line sustainability can be measured without a more thorough approach to the development of social indicators. The case study provided here, of the development of a social inequality footprint using social satellite accounts with data from MRIO tables, provides an example of how SNA consistent data can be used to provide more robust social and well-being indicators for use in measuring societal progress or sustainability. Social accounting with input-output analysis can provide quantitative answers to qualitative questions around well-being and society. The use of social satellite accounts with IO analysis is a developing area of economics and social analysis. In addition to the further application of this methodology, the development of a UN accepted system for socio-economic accounting would benefit developers of the data as well as policymakers and analysts globally when developing sustainability indicators and measuring social progress.

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CHAPTER 4: GLOBAL SUPPLY CHAINS OF COLTAN: A HYBRID LCA STUDY USING A SOCIAL INDICATOR

ABSTRACT

The spot price for tantalum, a metal used in high performance consumer electronics, spiked in 2000 triggering a boom in artisanal mining of surface deposits in the Democratic Republic of Congo (DRC). The profit from columbite-tantalite ore, or coltan, is alleged to have funded militants during that country's civil war. One warlord famously claimed that in 2000 coltan delivered a million dollars per month. While coltan mining was neither a necessary nor sufficient cause for the civil war there is nevertheless a clear association between mining and conflict. In order to trace global flows of coltan out of the DRC we used a high-resolution multi-region input-output (MRIO) table and a hybrid life cycle assessment (LCA) approach to trace exports through international supply chains in order to estimate a "coltan footprint" for various products. In this case study our aim is to highlight the power and utility of hybrid LCA analysis using high resolution global MRIO accounts. We estimate which supply chains, nations, and consumer goods carry the largest loads of embodied coltan. This hybrid LCA case study provides estimates on illicit flows of coltan, estimates a coltan footprint of consumption, and highlights the advantages and challenges of using hybrid monetary-physical input-output / LCA approaches to study and quantify a negative social impact as an input to production. If successful, the hybrid LCA approach could be a useful and expedient measurement tool for understanding flows of conflict minerals embodied in supply chains.

Keywords: Multi-Region Input-Output analysis, hybrid LCA, structural path analysis, coltan, social supply chain, conflict minerals

INTRODUCTION

Tantalum is a rare metal important in modern high-performance electronics including mobile phones and laptops. The Democratic Republic of Congo (DRC) is endowed with large surface deposits of the ore. But mining in the country is largely controlled by paramilitary groups and the profits are alleged to have substantially fuelled civil war in the country (UN Security Council 2002). The mineral has often been likened to blood diamonds, and electronics manufacturers and consumers have taken an increasing interest in avoiding "conflict coltan".

Tantalum is highly heat and corrosion resistant and a good conductor. It is an important component in a range of alloys and is used in a range of specialized applications including electronic and medical devices, prosthetics, optical lenses, aerospace engines, and cutting tools (Tantalum-Niobium International Study Center 2012). Its most important use, however, is in high performance capacitors, particularly in devices where size and weight are at a premium. While pure tantalum is a conductor, oxidized tantalum is a resistor, thus a single tantalum pellet with an oxidized exterior can be used as both the anode and the dielectric in a capacitor, eliminating the need for a separate dielectric material. Together with its high heat resistance this means that tantalum capacitors can be made small and dense, making them valuable for size-constrained high performance electronic devices including laptops and cell phones.

Australia, Brazil, Canada are the largest producers of columbite-tantalite ore. Those countries were estimated to have supplied 47%, 17%, and 5.5%, respectively, of total production in 2000 (USGS 2002). We identify DRC-sourced columbite-tantalite ores (12.5% of total production in 2000) by calling them *coltan*. In 2000 the price of tantalum spiked tenfold, rising from $30/lb to $300/lb (US Geological Survey 2001b). The exact reasons for this spike are not clear: sharply rising demand for laptops, speculation and hoarding, a new generation of battery-intensive mobile phones, and the popularity of the Sony PlayStation 2 have all been floated as potential triggers (Nest 2011). Most tantalum is delivered via long-term contracts between mining corporations and refiners. The DRC holds substantial easily-accessed surface deposits (which can be worked similarly to manual surface gold mining) and the price spike incentivized artisanal miners to supply coltan on the spot market. With a government already shattered by years of civil war, armed groups promptly found ways to capitalize on this mining.

The UN issued a series of reports (UN High Commission on Human Rights 2010; UN Security Council 2001, 2002, 2003, 2008) identifying coltan mining as funding armed conflict in the DRC and called the international companies buying illegal coltan "the engine of the conflict in the DRC" (UN Security Council 2001) (UN Security Council 2001) §IV.215. There was a strong focus on identifying how the export of coltan helped fund and support warlords and factions in the DRC. The UN reports linked artisanal mining in the DRC with social ills including extortion, use of child labour, unacceptable labour conditions, violent contests over mines, and environmental degradation including thousands of elephants and gorillas killed as bushmeat for mining camps (Hayes and Burge 2003).

The human toll was even greater. Civil war in the DRC resulted in approximately 350,000 violent deaths between 1998 and 2001 (Roberts et al. 2001) and has induced an estimated 2.5-9 million excess casualties since 1998 (Coghlan et al. 2006; Roberts et al. 2001) due to war-related social disruption, primarily reduced health care availability and the related spike in child mortality.

Coltan mining was neither entirely responsible for, nor linearly driving, conflict-induced deaths in the DRC. A recent study from The Hague Centre for Strategic Studies (Usanov et al. 2013) investigated the links between coltan and conflict and paints a more nuanced picture of the

causal links between mining and conflict. Mining was neither a sufficient or necessary cause of the civil war. Conflict deaths would have no more dropped to zero were coltan banned than has elephant hunting ceased since the ivory trade was outlawed. But there is an association between deaths and mining output. Were mining stopped (or, more realistically, exports banned) warlords would have had to turn to marginally less profitable income sources, thus reducing the intensity of the civil war. Warlords proceeded through a number of funding sources including diamonds, hardwood, and other resources, to fund their militias (Nest 2011). One cannot say that cutting the trade in coltan in half would have reduced deaths by half, but reducing the trade in coltan would have reduced the militias' funding options and would arguably have thus – at least at the margin - reduced the aggressors' ability to wage war. It has been argued that a total ban on coltan could cause more economic harm to workers than militias (Aronson 2012; Dizolele 2012). But the recent passage of the §1502 of the Dodd-Frank Act by the US Congress expresses a contrary opinion, namely that reducing trade in conflict coltan is desirable.

We sought to estimate global flows of embodied coltan in the year 2000 using hybrid LCA methods. In addition to providing interesting retrospective findings we are interested to see how effective hybrid LCA / MRIO methods can be for tracing hard-to-quantify social impacts. Hybrid LCA studies could be conducted comparatively quickly and could prove to be a useful method for organizations to study social impacts associated with production.

Tools from the field of industrial ecology (Graedel and Allenby 1995) have long been used to trace flows of metals and other substances of concern (e.g. Graedel et al. 2013; Graedel et al. 2002; Reck and Graedel 2012; Reck et al. 2008). The technique of hybrid life cycle analysis (Suh and Huppes 2000; Suh and Nakamura 2007) allows flows to be traced through more complex systems documented by input-output tables. To trace global flows of embodied coltan we used a hybrid LCA approach based on a high-resolution global multi-region input-output model.

SOCIAL LCA

Social Life Cycle Assessment (S-LCA) has become a popular tool for understanding the social impacts of production for a particular product or service. Particularly when combined with MRIOA, MRIO/S-LCA analysis can provide a bottom up/top down method for assessment. Guidelines for the Social Life Cycle Assessment of products were released in 2009 (Benoît and Mazijn 2009) and the Methodological Sheets for the Subcategories of Social LCA in 2013 (Benoit-Norris et al. 2011; Benoit Norris et al. 2013). The strengths of S-LCA (as opposed to other forms of social assessment) are the ability to focus on a product and the ability to encompass a broad range of social impacts ranging from producer behaviour to socio-economic well-being (Zamagni et al. 2011). However, as they also identify, weaknesses in this methodology also exist. The focus on an individual product (or functional unit) can draw the production boundary line too narrowly, thus missing social impacts such as child labour, hidden elsewhere in the supply chain. Another issue raised is the relevance of the geographical and cultural context of production. The example provided is of a car manufacturer producing the same make of car in several different countries – although the product is the same, the social impacts may not be. Achieving a balance between impacts on the whole of society versus the social impacts along a company supply chain can also be difficult (Zamagni et al. 2011).

S-LCA studies to date range from products as varied as a laptop computer (Ekener-Petersen and Finnveden 2013) to strawberry yoghurt (Benoit et al. 2011). For the S-LCA of a laptop computer, the full supply chain of a laptop computer had to be simplified to enable a hotspot assessment. When considering resource extraction, the study found that a generic laptop was

made up of more than 50 materials, and due to the complexity the study focussed on only seven components. It should be noted that the study did identify the DRC as a country with 'severe impacts', however as the weight of material sourced for the production of a laptop was relatively low the issue of ongoing conflict in the DRC linked with resource extraction was not strongly captured (Ekener-Petersen and Finnveden 2013). This study also highlighted some methodological shortcomings in S-LCA – the inability to measure real social impact, the difficulty in finding real data and the need for simplification. In a study of the sustainability assessment of how new technology can both contribute to sustainable development and take away from it, the authors found that the lack of data available using the S-LCA approach for developing countries was a significant problem, lack of indicators was also problematic and the methodology not yet feasible for the given case study (Lehmann et al. 2013). Jørgensen *et al* considered the impact pathways in relation to the 'Area of Protection' (Jørgensen et al. 2010) using S-LCA, with particular reference to child labour and wellbeing. This study found difficulty in getting relevant data and boundary setting issues. The difficulty in highlighting a pathway between an objective social indicator and subjective well-being was also raised. They state that "*The inclusion of subjective indicators necessitates an assessment of the experience of the actually impacted stakeholder*."(Jørgensen et al. 2010). Although highlighted as a difficulty in their study, our study does use a social indicator that provides an assessment of direct experience of the stakeholder. Lack of data and the use of proxy indicators can be a shortcoming for both S-LCA and MRIOA. However, where MRIO analysis can work well with S-LCA is to overcome issues with boundaries, whether they be product or country specific. Used together, LCA and MRIOA can provide both depth and breadth to the analysis of social impacts of production. Examples of this are beginning to emerge, such as the Social Hotspot Database which combines S-LCA with MRIO analysis provided by the GTAP database (Benoit-Norris et al. 2012).

DATA AND METHODS

We used Input-Output analysis (Leontief 1986a) and Structural Path Analysis (Suh and Heijungs 2007) to trace coltan flows from the DRC through international trade routes in order to map coltan's global supply chain network, and to calculate a "coltan footprint"[1] for various consumer products. We sourced data from the aforementioned UN reports, research by Nest (2011), and other sources, and integrated it into a global Multi-Region Input-Output database using a hybrid life-cycle approach. The complete global coltan trade network can be systematically documented, and trade routes can be traced not just to buyers and refiners but through multiple trade and transformation steps to final consumers. In this study we describe how we organized existing data on coltan in an input-output structure and used Leontief footprints and structural path analysis to trace coltan to final consumers. Input-output analysis has traditionally been of limited use in studying social issues so our work represents a new contribution not only to the literature on coltan, but also to the nascent field of S-LCA.

We used a hybrid approach combining Life-Cycle Assessment (LCA) with a Multi-Region Input-Output (MRIO) database (Bullard et al. 1978; Heijungs et al. 2006; Suh 2004; Suh and Nakamura 2007; Wiedmann et al. 2011c). Hybrid LCA does not refer to any single technique but rather refers to any study which attempts to marry LCA-based inventories with IO-based accounts, either by extending an LCA analysis using IO-accounts to provide information about background systems or by augmenting an IO using superior disaggregated data, as has been done in this study. In this method superior data on coltan-related transactions is used to split existing mining and metals processing sectors in the MRIO into coltan and non-coltan-related

[1] Not to be confused with the chemical tagging technique of "coltan fingerprinting".

subsectors. We will first discuss the coltan-related data that we collected and then explain the MRIO disaggregation procedure.

DATA

A number of assumptions were made during the disaggregation process. First, we made an assumption about the spot-market price of coltan. In 2000 the spot price for tantalum ranged from US $30/lb to over US $300/lb (US Geological Survey 2001b). Unlike as with typical long-term mining supply contracts this spot-market price can vary widely, and as tantalum is not traded on a metals exchange there exists no definitive price record. Further, the price paid for ore will vary between points along the long supply chain leading from the artisanal diggers through various transporters, traders, and exporters to the refiners. Finally, the conflict coltan in question was sold at informal markets where prices doubtless differ from those published in the weekly metals bulletins. The US Geological Survey (USGS) quotes an average price of $219/lb for the calendar year 2000 (US Geological Survey 2000, 2001a), though prices varied, as noted above. A price of $220/lb was assumed unless better data could be found. Variations in the price per kilogram between locations, ore grades, and short-term fluctuations make it difficult to accurately convert between physical and monetary units.

The UN Security Council reports that coltan mined in the DRC in 2000 was exported both directly to refiners and transported via the porous borders through neighbouring Rwanda and Uganda. Nest (2011) estimates that half of Rwandan coltan exports in 2000 were actually mined in the DRC. Rwanda is not a traditional producer but it has accessible surface deposits similar to the DRC. However since artisanal mining in Rwanda (and to a lesser degree in neighbouring Burundi and Uganda) is less ethically worrisome than DRC artisanal mining this study focused exclusively on DRC-originated coltan. The Rwandan transportation sector appears in some of the results but this is solely a transportation stage; only DRC-sourced coltan is being traced.

The US, Germany, and China are home to major refiners (e.g. Kemet, AB Singher, and Nixon). These companies were implicated in the UN reports as buyers of smuggled coltan. In our analysis in addition to assuming coltan was sent to these countries it was also assumed that the processing plant in Kazakhstan was a major buyer of DRC coltan in 2000, buying $5.5 million of the $33.9 exported from DRC that year. The UN reports identified Kazakhstan as a recipient of coltan mined in DRC in 2000, an allegation the Kazakh government has neither confirmed nor denied (UN Security Council 2001) §22. The Ulba manufacturing plant of national processor Kazatomprom began selling capacitor-grade tantalum in 2001 (Kazatomprom Ulba Metallurgical Plant 2012) and based on our research we believe it is unlikely the plant was fully supplied by long term contracts at that time. Tantalum imports into Kazakhstan in 2000 were estimated based on data from UN COMTRADE (United Nations Statistics Division 2007). Specific data were not available for 2000 on tantalum so the value for niobium/tantalum imports into Kazakhstan in 2002 was used as a proxy. Of the US$5,548,500 assumed imported to Kazakhstan in 2000, 40% was assumed to arrive directly from DRC and 40% indirectly via Rwanda.

The USGS Tantalum Niobium Commodity Report (US Geological Survey 2000) was used to determine trade flows between DRC, Rwanda, Kazakhstan and the US. One limitation of our study is that some refining or value-added production using coltan could potentially be unreported or conducted by black market actors. Such activities would not be recorded in the MRIO table, since MRIO tables do not typically record black market or unreported transactions (except in very rare instances where they have been specifically estimated by the relevant national statistical agency). However coltan refining and processing requires relatively sophisticated technology and there is no reported evidence of black market refining or

processing so it may be assumed that the omission of the black market in refining is not a major shortcoming in this study.

METHODS

Based on the data and assumptions outlined above, information from Nest (2011), and the UN Security Council reports, a trade network was quantified linking the DRC with Rwanda, Kazakhstan, Germany, China, and the USA. We employed hybrid LCA to insert transactions data representing this network into a global MRIO table from the Eora database. The Eora MRIO table (Lenzen et al. 2012a) used in this study covers 187 countries with 26-500 sectors per country. The original MRIO sectors containing the coltan-related sectors were disaggregated (split) into a new coltan-related sub-sectors and the remaining original sector, so that coltan flows could be traced separately (see
Table 1; compare with the technique used by (Liu et al. 2012)).

Like many LCA and IO studies this method is attended by some systematic sources of uncertainty, including from the use of a monetary model to trace physical flows (and the subsequent uncertainty due to fluctuating prices), and the constant need for more data and resolution with which to more accurately trace which particular products flow through which particular sectors. In this study our aim is merely to make an initial estimate of the coltan footprint. We do not assert that with the limited data available for this study that the findings are ready for any policy application. With more data on transactions, and more confidence in these data, we would be able to further improve the reliability of the findings.

Country	Remaining original sector and new subsector
DRC	Mining and Quarrying Coltan Mining
Rwanda	Mining and Quarrying Coltan Transportation
Kazakhstan	Non-ferrous Ores Coltan Processing
USA	Electronic capacitor, resistor, coil, transformer, and other inductor manufacturing Coltan Processing
Germany	Other metallic ores Coltan Processing

TABLE 1: SECTOR DISAGGREGATION: NEW SUBSECTORS WILL CONTAIN COLTAN-SPECIFIC TRANSACTIONS.

The MRIO is augmented by using data on coltan transactions. Data points on coltan transactions were inserted into the new sectors based on data collected on coltan exports from DRC and Rwanda, tantalum imports and exports into and out of Kazakhstan, and tantalum imports and exports into and out of the USA. Table 2 describes coltan transactions in an input-output format. Origin sectors are listed row-wise and destinations sectors column-wise; e.g. the Kazakh Processing sector buys $2.2 million worth of coltan ore from both the DRC and Rwanda, and sells $0.9, $2.6, and $0.9 to the American capacitors industry, Chinese electronics industry, and other sectors, respectively. The only input (read Table 2 column-wise) to the DRC Coltan Mining sector is raw ore (primary inputs) which it exports (read Table 2 row-wise) to transportation and processing sectors. The $33.9 million of coltan originating in the DRC flows both directly and indirectly, via Rwandan transporters, to processing industries in Germany, Kazakhstan, and the USA. These processing sectors then sell products to electronics sectors and All Other Sectors. In this table unsigned values are inserted directly, (+) signed values are added to the

pre-existing transactions from the original MRIO, and (-) signed values are subtracted from the pre-existing transaction in the MRIO. Further data on coltan flows could be added in the same manner to further improve the accuracy of the model. The "All other sectors" row and column actually condense the other ≈15,000 individual sectors in the Eora MRIO table. The adjustments in those columns are pro-rated out amongst those ≈15,000 sectors using either the original sales mix of the source sector (for positive adjustments) or the input recipe of the destination sectors (for negative adjustments). A total of $33.9 million in coltan inputs are added and a total of $33.9 million of other normal inputs are subtracted so the modified IO table remains balanced; that is, the column sum of each sector (the sum of its inputs) equals its row sum (the sum of its sales).

million USD (2000) Destination: / Origin:	DRC Mining & Quarying	DRC Coltan Mining	Rwanda Transportation	Kazakhstan Processing	Germany Processing	Germany Electronics	USA Processing	USA Capacitors	China Electronics	All other sectors
DRC Mining & Quarying										
DRC Coltan Mining			17.0	2.2	10.2		3.4			***+1.2***
Rwanda Coltan Transportation				2.2	8.5		5.9			***+0.3***
Kazakhstan Processing								0.9	2.6	***+0.9***
Germany Processing						13.1				5.6
Germany Electronics										
USA Processing								9.3		0
USA Capacitors										
China Electronics										
All other input sectors						***-13.1***		***-10.2***	***-2.6***	***-34***
Primary Inputs		33.9								

TABLE 2: AUGMENTING THE MRIO TABLE WITH COLTAN TRANSACTIONS. NEW SECTORS ARE ITALICISED. UNSIGNED VALUES ARE INSERTED INTO THE MRIO TABLE, (+) SIGNED VALUES ARE ADDED TO THE PRE-EXISTING TRANSACTION VALUE, AND (–) SIGNED VALUES ARE SUBTRACTED FROM THE PRE-EXISTING TRANSACTION. VALUE CHANGES TO "ALL OTHER SECTORS" ARE DISTRIBUTED ON A PRO-RATA BASIS. BLANK CELLS ARE NOT ZERO BUT ARE TAKEN FROM THE SOURCE MRIO; THIS TABLE MERELY HIGHLIGHTS THE AUGMENTATIONS TO THE BASE MRIO.

Using the Leontief inverse calculus it is possible to link demand for coltan to final consumers. Using the $S \times S$ Eora MRIO table $\mathbf{T}$ containing transactions between S = 14787 sectors, the coltan footprint $\mathbf{F}$ $(1 \times S)$ in terms of mineral mined in the DRC resulting directly and indirectly from an environmental satellite account containing the value of coltan used as input in that sector. In this case $\mathbf{Q}$ contains only a single nonzero element, which is $33 million in the DRC Coltan mining sector. Note that in environmentally extended input-output analysis the satellite account may contain nonmonetary units so the same method could be used to calculate the Coltan footprint not in $ of coltan but in Kg or, potentially, number of conflict-induced deaths

associated with Coltan production. The term $\mathbf{Q}\hat{\mathbf{x}}^{-1}$ contains the coltan content of each sector's

production, in terms of $ coltan per $ gross output, for each sector. The term $(\mathbf{I} - \mathbf{T}\hat{\mathbf{x}}^{-1})^{-1}$ [2] is the classic Leontief inverse. All analysis was conducted in terms of producers prices.

FINDINGS

The results indicate Germany, the USA, China, the UK, and Japan ultimately consumed a total of 58% of the coltan mined in the DRC in 2000 (Table 3). The results of the hybrid LCA method are immediately apparent: even though the UK, Japan, France, and other countries do not directly import or process any coltan, consumers in those countries use a substantial amount of coltan embodied in products. Here we shall use the term "embodied" in a slightly nonstandard manner. Typically the term refers exclusively to indirect use; e.g. if tungsten carbide tools are used to produce a car, that car is said to include embodied tungsten even if the vehicle itself contains no actual tungsten. Coltan is used in products both indirectly, for example in cutting tools used to produce cars, and also directly, for example in capacitors in an engine control computer. Here we use the term "embodied" to refer both to the indirect and direct coltan used by a product. The analysis is conducted in monetary, not physical units, and since the price of coltan varies widely, rather than attempting to convert the monetary flows to physical units we report flows in monetary units.

Country	Percentage of total Coltan consumed in 2000
Germany	18%
USA	14%
China	14%
UK	7%
Japan	6%
France	4%
Italy	4%
Canada	3%
Spain	2%
Netherlands	2%
All others	26%

TABLE 3: CONSUMERS OF DRC-SOURCED COLTAN IN 2000, AS SHARE OF TOTAL GLOBAL COLTAN FOOTPRINT.

In the scenario as modelled we find that Germany is a disproportionately heavy user of embodied coltan. This is because German (and to a lesser degree, US) plants were primary buyers of implicated coltan. Kazakhstan was also a buyer; however final consumption of electronics and implicated products in Kazakhstan is much lower – much of these are exported – meaning Kazakhstan is essentially a middleman, not end user, of implicated coltan. Since German processing firms likely used coltan, German electronics have higher loads of embodied coltan.

[2] In the input-output literature the term $\mathbf{T}\hat{\mathbf{x}}^{-1}$ is often abbreviated as **A**, the technical coefficients matrix containing the input A_{ij} needed from sector *i* to produce 1 unit of output from sector *j*.

Using structural path analysis (Lenzen 2002; Suh and Heijungs 2007; Treloar 1997) it is possible to identify important international supply routes through which coltan flows from the DRC coltan mining sector out to final consumers. Many of these flow through the Rwandan transportation sector. The top such paths are shown in Table 4.[3]

Path Value (m USD)	Path
$2.0	DRC → Germany Processing → Final consumption in Germany of communication and electronic equipment products
$1.7	DRC → Rwanda → Germany Processing → Final consumption in Germany of communication and electronic equipment products
$1.0	DRC → Germany Processing → Final consumption in Germany of office equipment products
$0.9	DRC → Rwanda → USA Processing → Final consumption in USA of electronic capacitor, resistor, coil, transformer, and other inductor manufacturing products
$0.8	DRC → Rwanda → Germany Processing → Final consumption in Germany of office equipment products
$0.5	DRC → USA Processing → Final consumption in USA of electronic capacitor, resistor, coil, transformer, and other inductor manufacturing products
$0.4	DRC → Kazakhstan Processing → Final consumption in China of electronic computer products
$0.4	DRC → Rwanda → Kazakhstan Processing → Final consumption in China of electronic computer products
$0.3	DRC → Kazakhstan Processing → Final consumption in China of communication equipment products
$0.3	DRC → Rwanda → Kazakhstan Processing → Final consumption in China of communication equipment products

TABLE 4: TOP 10 SUPPLY FLOWS OF COLTAN FROM THE DRC TO FINAL CONSUMERS, AND ESTIMATED MAGNITUDES IN TERMS OF VALUE ($US MILLION). A PATH VALUE OF $2 MILLION INDICATES THAT $2 MILLION WORTH OF EMBODIED COLTAN FROM DRC THROUGH THE SPECIFIED PATH TO REACH THE SPECIFIED FINAL DEMAND SECTOR.

Coltan is famously used in mobile phone batteries. One representative path is "DRC → Rwanda → USA Processing → USA electronic capacitor, resistor, coil, transformer, and other inductor manufacturing products → Final demand in South Korea in the radio, television and communications equipment sector" showing ≈$75,000 worth of coltan (0.22% of coltan mined in 2000), embodied in what are most likely electronics within game consoles and mobile phones purchased by Koreans.

More obscure paths can also be traced. For example the path "DRC → Rwanda → USA Processing → USA electronic capacitor, resistor, coil, transformer, and other inductor manufacturing products → Mexico manufacture of transport equipment industry → Final demand in Mexico in the manufacture of transport equipment sector" shows ≈$57,000 worth of coltan flowing out of DRC via Rwanda to US processors and then into vehicle components for vehicles bought by Mexican consumers. This embodied coltan could be used in cutting tools used in factories, in corrosion resistant bolts in the vehicles, or directly in the vehicle electronics including in the airbag system, ignition system, motor control module, GPS, or antilock brake system. This particular path contains ≈$57,000 worth of coltan. A similar path, but through German processors into Spanish vehicle manufacturing contains ≈$12,000 worth of coltan implicated.

Yet another path shows ≈$40,000 worth of coltan (0.12% of year 2000 production), flowing from DRC → Rwanda → Germany Processing → Germany communication and electronic

[3] If enumerated completely this list of paths would be mutually exclusive and collectively exhaustive, but since the value of smaller paths approaches zero is it not computationally efficient to trace more than the top hundred thousand or so (Lenzen 2006b).

equipment products → Final demand in Germany in the medical, scientific, optical equipment, watches sector. This embodied coltan could be embodied in hearing aids, pacemakers, suture clips, coated on medical implants, used to produce X-ray film, or included in trace amounts in camera optics or in the electronics in a digital camera.

Coltan is also used in aerospace applications as an alloy in high temperature steels. This is a smaller use than in electronics, but still a notable one. The flows "DRC → Germany Processing → Final demand in Germany in the air transport sector" and "DRC → Rwanda → USA Processing → USA electronic capacitor, resistor, coil, transformer, and other inductor manufacturing products → USA general federal defense government services industry → Final demand in USA in the general federal defense government services sector" include coltan embodied in alloys used for jet engines, rocket engines, and chemical process equipment.

CONCLUSIONS

Our basic motivation for this study was to highlight the utility of hybrid LCA as a method for tracking social indicators in general, and a method for tracing global coltan flows in particular. While there is general agreement that conflict-source coltan should be illegal, there has been comparatively little work done to try and identify the major flows of coltan. This is where tools from industrial ecology can be brought to bear. Research into trace, critical, and major flows of materials has been one of the core objectives of industrial ecology since the outset.

Tracing the supply chains using coltan reveals that the mineral is widely used. Hybrid LCA is a powerful tool for elucidating the global supply chains connecting producers to consumers. The method both provides a consistent framework in which various data sources can be organised and also enumerates the global supply chains connecting consumers to local problems.

There exist many approaches to tracing substances of interest, including material flow accounting in which physical inventories are traced, and bottom-up LCA methods. The former is highly accurate yet difficult to implement and can usually only be applied once a system is in place, not retrospectively to substances of interest. Bottom-up LCA approaches can be used to estimate either physical flows or embodied flows, and can be based on mixed economic and physical data. However LCA approaches are quite reliant on data availability, and also the bottom-up approach can allow analysis to miss flows that would be indicated by a top-down analysis. The hybrid MRIO method is admittedly less accurate than either of these two approaches, however a study can be executed quickly, and retrospectively. The choice of which tool to use to study a flow of interest depends highly on the level and detail of data available and how much time is available to execute the study. As a next step for studying embodied flows of Coltan the major flows from this top-down analysis could be used as the starting point for bottom-up LCA studies that start by investigating those flows. One outcome of the Dodd-Frank ruling could be that major tantalum users start to audit their tantalum supply chain, thus effectively implementing a mass flow analysis.

Policy responses to address the problem of conflict coltan have had mixed success. The conclusions of the UN reports on coltan were frank and disheartening: "[T]he exploitation of natural resources that does not benefit the majority of the Congolese people is not a new phenomenon… In the absence of a strong, central and democratically elected Government that is in control of its territory, illegal exploitation will continue…" (UN Security Council 2003) §48. Various initiatives to constrict the trade in conflict coltan have been put forth. These have include UN Security Council resolutions, a certification program from the German ministry of economic development, the Durban Process (modelled on the Kimberly process for conflict diamonds), Section 1502 of the Dodd-Frank Act (US Securities and Exchange Commission

2012), and a number of NGO-led efforts addressed both to supply chain partners and consumers. Yet for the most part these measures have been too little too late. These controls were only erected years after the problem was first identified. Additionally, the more stringent certification requirements have been criticized both for enacting a *de facto* ban on Congolese coltan production that hurts workers more than militias and for not addressing the true problem of weak government (Aronson 2012; Dizolele 2012).

Since coltan is valuable and easily mined, ethical concerns over artisanal scale mining (as opposed to mining by accountable larger corporations) are likely to persist wherever small coltan surface deposits are worked. China has recently expressed interest in Colombia's substantial surface reserves (Walsh 2012a) and Colombia has stepped up regulation against illegal mining (Molinski 2012). Coltan mining is also illegal in neighbouring Venezuela, but surface deposits lying along the Colombia/Venezuela border are already worked by small-claim miners (Diaz-Struc and Poliszuk 2012) and have reportedly drawn the interest of FARC rebels (Fox 2012; Walsh 2012b). Together these factors set the stage for increased illegal mining activity in this region, with the spectre of associated violence.

The problem of conflict minerals is unlikely to disappear. Violent contests will persist wherever there are valuable resources and weak governments. The public and private sectors have been slow to respond to the issue of conflict coltan. We believe this is due in a large part to lack of transparency. Shortly after the problem flared up in 2000 good information became available on the scope and structure of the problem (from the UN and other sources), but efforts to trace coltan were not able to follow the mineral beyond the major processing firms. Using estimation techniques, as has been done here, to trace these flows fully out to consumers could have provided first-order estimates of the major flows, implicated products, and biggest consumers. Such information could have been used to accelerate policy response, corporate transparency, and certifications of coltan-free supply chains. The focus on getting major consumer facing electronics companies (e.g. Apple), rather than intermediate suppliers or individual products, to become completely "coltan free" seems a good strategy. Fully accountable traces using physical methods, such as chemical fingerprinting (Melcher et al. 2008) or the Kimberley Process to control conflict diamonds may be overkill, and slow to implement. The chemical fingerprinting technique took 8 years to develop and the Dodd-Frank formal disclosure rules took 12 years to enact. Hybrid LCA techniques could provide improved transparency into global coltan flows with much less time and effort.

Both the domestic situation and controls on conflict coltan from DRC have improved since 2000. Our aim in this initial study has not been to inform policy regarding this particular conflict mineral, but rather to highlight how hybrid LCA methods, in conjunction with high resolution MRIO tables, can provide a useful tool for tracing global flows of substances of social concern.

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CHAPTER 5: COLTAN: A STUDY OF ENVIRONMENTAL JUSTICE AND GLOBAL SUPPLY CHAINS

ABSTRACT

As global trade barriers are reduced and citizens become more readily connected, supply chains have gone global. Not only are the products global – someone can be holding the same model of phone in China as they are in London – but so are the supplies and suppliers. A mineral can be mined in Africa, exported across porous borders to be transported for processing in Europe, sent to Asia for manufacturing and end up in the hands of consumer in North America. This is the story of coltan, a mineral commonly mined as tantalum in countries as diverse as Australia and Brazil, but that rose to notoriety for its production in the Democratic Republic of Congo. The story of the production of coltan in itself is interesting – mine working conditions, the funding of war, citizenship and borders, governance and government, loss of habitat and life, intervention and the role of public campaigning. Beyond these issues an even bigger question needs to be asked – how, as global citizens, can we influence or control supply chains? Through analysing a quantitative case study of the supply chain of coltan in 2000, this chapter considers the role of environmental justice with respect to supply chains. Various programs have been put in place since 2000 to try to reduce the negative human and environmental impacts associated with mining coltan. These include governance and diplomacy, formal processes for certification, establishing conflict free mines, identifying alternative sources, information and media campaigns, and most recently the enactment of legislation for disclosure. By reframing supply chain management as a cross disciplinary issue for citizens in the global marketplace, the application of environmental justice may be critically examined.

Key Words: Coltan, supply chain management, environmental justice, Congo, social footprint, multi-regional input-output analysis.

INTRODUCTION

If we look back 300 years, most supply chains were short and quite simple. Many commodity supply chains extended only to the local town or nearby trading towns, supplies were bought and sold from within each country. As the 20th progressed into the 21st century, supply chains became increasingly complex. Efficient transportation, mass supply, reduction and removal of trade barriers and variability in the cost of labour and legislated standards mean that products are sourced from and transported to anywhere in the world.

The variability in labour and environmental standards is particularly relevant when considering environmental justice in a global market. This chapter seeks to address how consumers can influence environmental justice (including social justice) outcomes upstream in the supply chain, when faced with evidence of human rights and environmental abuses. To illustrate, multi-regional input-output (MRIO) analysis is used to generate a social footprint to quantify the death toll associated with sourcing coltan from the Democratic Republic of Congo (DRC) in 2000 and hypothetically allocate responsibility for deaths to end consumers around the globe. This chapter will then consider the current options for consumers seeking environmental justice and identify areas for future research.

COLTAN, MOBILE PHONES AND ENVIRONMENTAL JUSTICE

Through environmental justice campaigns, coltan is intricately linked with images of mobile phones and gorillas although the full story is more complex. Coltan is the colloquial name for the mineral compound columbite-tantalite, which can be processed to form tantalum. Tantalum (Ta) is a useful metal, having a high heat and corrosion resistance and, most importantly for the electronics sector, it is lightweight and an excellent conductor.1 Although used in many applications including medical devices, optical lenses, cutting tools and weaponry, one of the most well-known uses of tantalum is in high performance capacitors for electronic devices. This means that tantalum is found in most mobile telephones, smart phones, lightweight computers and games consoles. The raw colombite-tantalite ore is mined in many countries, including Australia, Brazil, Mozambique, Canada, DRC and Rwanda. Processed metal comes from sources including China, Kazakhstan and Germany and an increasing market in tantalum from scrap and waste (i.e. recycled) is coming from markets mainly in Estonia, Russia and Mexico.2

In an effort to make a rather unremarkable component mineral into a cause for justice, campaign groups in the 2000s linked coltan to mobile phones, and gorillas to coltan. Multiple campaigns sought consumers of mobile phones (ostensibly containing coltan) to either boycott using their phones, recycle their old phones or campaign for justice through their telecoms provider.3 The injustice attributable at least in part to the mining of coltan in the DRC includes death, violence and torture, rape, the breakdown of family units, poor labour conditions, high child mortality, child labour and loss of biodiversity.

The campaigns have continued to ring true as mobile phone use has become more ubiquitous and revolutionised life. Since the first public mobile phone call was made in New York in 1973, on a device weighing approximately 1kg, there are now approximately 6.5 billion mobile phone service subscribers worldwide.4 Mobile phones are revolutionising communication and the way people interact in Africa in particular, with over 650 million subscribers and the World Bank crediting the creation of over 5 million jobs on the African continent to the mobile phone industry. The outcomes of greater mobile phone penetration in Africa include poverty reduction, access to agricultural information, banking, clean water and education.5 In some African countries more people have access to a mobile phone than access to clean water or electricity. In 2000 there were 16.5 million mobile phone subscriptions in Africa. By 2011 this

had risen to 648 million subscriptions. The advent of affordable smart phones and the ability to run these devices off mobile broadband networks that require little infrastructure has helped Africans become global citizens, as well as bring about social and economic advances.6 As demonstrated with the uprisings in the Arab Spring, connectivity and global citizenship can be powerful forces for justice. What if the tool that is improving global citizenship and wellbeing is also implicated in environmental injustice?

The Information and Communications Technology (ICT) industry recognises that there are significant environmental and labour issues within its supply chains that go beyond coltan and mobile phones. These issues include poor working conditions in factories, child labour, exposure to chemicals and environmental hazards, enforced overtime and environmental degradation. Apple Inc has born a great deal of media attention for the conditions in factories of suppliers such as Foxconn in China but it is recognised that if these issues exist within the Apple Inc supply chain then they are likely to be repeated elsewhere.7

Part of the problem in seeking social and environmental justice for those impacted in the supply chain is the distance between the ultimate consumer and the producers. There is a 'democratic deficit:' whereas globalisation has brought people together through broadened markets and an increased mobility between states, it has also alienated people as distrust of government and corporations increases and with it comes an increasing feeling of powerlessness to effect global market decisions.8 Corporations have little incentive to bring about environmental or social change unless it is part of their core reason for being (e.g. social enterprises) or it directly affects their market. As sales of Apple Inc products have shown, even deaths directly linked to supply chain working conditions do not necessarily result in changed consumer behaviour.9

In addition to social issues, environmental justice campaigns relating to mobile phone production also look at the impact on the environment. In areas such as fishing there is clearly a link between good conservation management, sustainable (long term) business and profit.10 However this does not hold true for all industries. In the DRC, it was reported that during the coltan boom in 2000 it was suspected that all of the elephants and most of the eastern lowland gorillas in the Kahuzi-Biega National Park were killed, mostly for bush meat.11 The plight of the eastern lowland gorilla became one of the focal points in the consumer campaign for environmental justice in the DRC.

LINKING WAR INDUCED DEATHS TO COLTAN SUPPLY

Whilst the injustice associated with coltan mining in the DRC is incalculable, this research seeks to quantify the loss of life due to the mining boom in coltan in the year 2000, and hypothetically associate deaths due to the civil war funded by coltan with consumer end use to create a social footprint. In 2000, and for this year only, the sale of coltan was the greatest funding source for all sides of the civil war in the DRC. In all other years, natural resources such as diamonds, gold, copper, cobalt and timber were identified as being important for the generation of funding for the civil war.12 However, in 2000 there was a spike in the price paid for tantalum on the spot market, from $30/lb to $300/lb.13 This has been attributed to a number of reasons, such as demand for laptops associated with the dotcom boom, a new generation of mobile phones, the popularity of the Sony Play Station 2 or congestion in the minerals trading market due to long term contracts and stockpile.14

As tantalum is traded on the free market (as opposed to the metals market) and the ongoing civil war left warring factions searching for funding sources, artisanal mining of Congolese surface deposits (i.e. mining by individuals and small teams with very basic equipment) began in earnest. It was claimed by a Congolese warlord that in the year 2000 diamonds provided an

income of US$200 000 per month, whereas coltan could generate revenues of up to US$1 million per month.15 In the subsequent years, coltan made a few people very rich in the DRC and neighbouring countries but also caused incalculable damage to society and an estimated 5 million deaths up to 2010.16

From 2000 the UN Security Council investigated the conflict in the DRC and issued a number of reports that identified, amongst other issues, that coltan mining was funding the armed conflict and the sale of coltan to international companies had become '...the engine of the conflict in the DRC.'17 Without the sale of coltan conflict would not disappear, but the sale of coltan provided a source of funding that allowed the conflict to proliferate.18 To understand where the coltan ended up in the supply chain in 2000, and attribute deaths hypothetically associated with the coltan trade, we used a hybrid Life Cycle Analysis (LCA) with MRIO analysis.

Using MRIO analysis, millions of supply chains can be traced based on economic data. Through a painstaking interview process, the UN Security Council uncovered how coltan moved in 2000, out of the DRC, across porous borders into neighbouring countries such as Rwanda and on to third party traders and then processing. By combining this data with other research, an even better understanding can be gained of how raw materials flow as a path through the supply chain. The combined LCA MRIO approach is not new when used for assessing environmental impacts.19 It has even been used to map how international trade can drive biodiversity threats.20 Here the novelty is its use in quantifying social impacts in a supply chain to create a social footprint for coltan.

Whilst it is possible to observe injustice in a supply chain, it is often difficult to quantify. Many popular sustainable supply chain approaches, including surveys or site visits, encourage an understanding of the issues but do not contribute to quantification of the problem. By using economic data combined with qualitative and quantitative data, this study traced coltan from the source in the DRC, through porous borders with Rwanda, onto processing in Kazakhstan, Germany and the USA and to final markets around the world. Each of these supply 'paths' (representing the flow of money from one industry sector to another and in between countries) has a hypothetical number of war induced deaths associated with it (see Table 1). For a detailed outline of the case study data, methodology and assumptions see Moran et al (2014).21 The results of the analysis indicated that the top 440 paths account for half of the 2 million deaths estimated for the year 2000, while the top 15 paths (shown in Table 1) represent 552 150 deaths or 28% of the total.

Path Number	Deaths	Path
1	119,076	DRC -> Germany Processing -> Final demand in Germany in the communication and electronic equipment sector
2	99,230	DRC -> Rwanda -> Germany Processing -> Final demand in Germany in the communication and electronic equipment sector
3	56,313	DRC -> Germany Processing -> Final demand in Germany in the office equipment sector
4	54,155	DRC -> Rwanda -> USA Processing -> Final demand in USA in the electronic capacitor, resistor, coil, transformer, and other inductor manufacturing sector
5	46,928	DRC -> Rwanda -> Germany Processing -> Final demand in Germany in the office equipment sector
6	30,946	DRC -> USA Processing -> Final demand in USA in the electronic capacitor, resistor, coil, transformer, and other inductor manufacturing sector
7	21,282	DRC -> Kazakhstan Processing -> Final demand in China in the electronic computer sector
8	21,282	DRC -> Rwanda -> Kazakhstan Processing -> Final demand in China in the electronic computer sector
9	20,042	DRC -> Kazakhstan Processing -> Final demand in China in the communication equipment sector
10	20,041	DRC -> Rwanda -> Kazakhstan Processing -> Final demand in China in the communication equipment sector
11	13,029	DRC -> Kazakhstan Processing -> Kazakhstan Processing -> Final demand in China in the electronic computer sector
12	13,029	DRC -> Rwanda -> Kazakhstan Processing -> Kazakhstan Processing -> Final demand in China in the electronic computer sector
13	12,269	DRC -> Kazakhstan Processing -> Kazakhstan Processing -> Final demand in China in the communication equipment sector
14	12,269	DRC -> Rwanda -> Kazakhstan Processing -> Kazakhstan Processing -> Final demand in China in the communication equipment sector
15	12,259	DRC -> Final demand in Germany in the coltan processing sector

Table 1: Top 15 Supply Routes of Coltan Flowing from the DRC to Final Consumers in 2000. © Daniel Moran and Darian McBain 2012.

As we can see from Table 1 all of the top 15 paths end in the electronics, communication or capacitor sectors, implying that mobile phones were an end use for coltan but not the sole end use. These sectors would include many electronic goods, not just telephones. This has implications for the validity of some of the statements used in coltan environmental justice campaigns. Other supply chain paths within the top 100 analysed ended in uses as varied as the Mexican transport manufacturing sector, the German medical sector and the Canadian construction sector. Using this methodology, companies can work out their responsibility for the hypothetical death toll in that year by calculating their market share of the industry sector.

With a greater data certainty this methodology can be used to make real estimates of consumer responsibility rather than a hypothetical modelling presented here. Based on the data, it is possible to make policy decisions clearer or environmental justice campaigns more focussed. Using a willingness to pay/willingness to accept approach, it would be possible to calculate how much an individual is willing to pay for environmental justice, which may aid business decision making processes. This research makes an important contribution to understanding an individual's share of the responsibility for injustice. However, it raises an important question for global citizenship – what can an individual do to address this responsibility and influence environmental justice in the supply chain?

DISCUSSION: HOW CAN CITIZENS IN THE GLOBAL MARKETPLACE INFLUENCE ENVIRONMENTAL JUSTICE?

The focus on seeking environmental justice in a supply chain context has been polarised into corporate action versus consumer action. For consumers, the focus is primarily on direct action such as boycotting a product or company, avoiding a purchase through reuse or recycling, pressuring a company to change their behaviour, or asking third party retailers/suppliers to change their supply lines or influence their suppliers.

The focus on human rights and the supply of goods and services is increasingly on eradicating modern slave labour. Modern slavery covers human trafficking and enforced economic or sexual exploitation.22 International campaigns such as Walk Free23 focus specifically on supply chain action through consumer power and corporate leadership. Calls by governments such as Australia24 and the UK are seeking to ensure that there is no slavery or human trafficking in the supply chains of goods and services to government.

Governance within DRC must also be addressed – in addition to the UN Security Council resolutions themselves, the UN Security Council called for a democratically elected central government in the DRC which has the strength and influence to control trade and its borders.25 There is a recognition that business and governments need to work together on complex issues emerging around environmental protection, human rights and economic growth.26 Particularly where there is a weak government, environmental justice is unlikely to be enforced. Some believe that global capitalism has allowed corporations to generate unsustainable profits at the expense of the environment and society by transcending national and state boundaries and avoiding relevant regulation.27

Supply chain partnerships and certification can provide both consumers and corporations with greater certainty of justice within a supply chain. One report identified over 10 supply chain initiatives aimed at the electronics sector, most of which failed due to a number of breakage points in the supply chain and lack of commitment/funding by supply chain partners.28 A German programme for 'fingerprinting' coltan to identify its source of origin is providing some success for certification, but issues with coltan extend beyond just the origin of the material and into the whole of the supply chain.29 Supply chain certification processes such as the Durban

Process for Ethical Mining (based on the Kimberly Process used to control conflict diamonds) have had difficulty in implementation and finding the correct supply chain partners to support the process. New methods are emerging to trace (and potentially certify) supply chains. For example a study in Africa identified that the use of a mobile supply chain management and equipment tracking system enabled for mobile phones could revolutionise the tracking and supply of medical equipment.30 A similar system could be used for tracking conflict minerals, providing both local ownership of relevant parts of the supply chain and an option for certification.

Another approach may include a greater focus on understanding supply chains and consumer preferences. The 2013 scandal regarding the undisclosed sale of horse meat in UK food products demonstrates that even when companies have good supply chain practices in place, vigilance and understanding consumer low/zero tolerance issues is important. The supermarket chain Waitrose, well known for its ethical approach to supply chain management, reported an 11% increase in sales in the quarter following the scandal.31 These low/zero tolerance issues often fit within the paradigm of environmental justice – child labour, death of workers, cruelty to animals (particularly charismatic animals or those that are frequently anthropomorphised), destruction of valued environments. Having a supply chain certified to high environmental and social standards can bring about a market and competition delineator.

For corporations seeking to avoid use of conflict minerals there are several sources of information32 as well as emerging regulation. As part of the financial reforms in the US Dodd-Frank Act 2010, Section 1520 requires listed companies to report publicly on the source of conflict minerals (tin, tungsten, tantalum and gold), and if the source is the DRC further demonstration that the sourced material is conflict free is required.33 There is concern that the implementation of SEC 1520 will remove a vital source of income from the DRC if companies source only from non-conflict countries. There is also concern that other emerging sources of tantalum, such as Venezuela and Colombia could be funding conflict.34 Total supply chain control is demonstrated through Solutions for Hope.35 This project was established by Motorola Solutions Inc (producer of communications equipment) and AVX Corporation (producer of tantalum capacitors) in July 2011. They have created a conflict free closed pipe supply chain from miners in the DRC to smelting, component manufacturing and end user. The project is still in operation, and in 2013 the first available conflict free smartphone using the conflict free supply chain was available through Fairphone.36

Consumer campaigning on the issue of coltan has generally focussed on minimising the use of tantalum from conflict sources through alternative providers and boycotts (e.g. Conflict Free Campus Initiative), encouraging companies to trace, audit and certify their tantalum supply chain (e.g. Enough project) and minimising consumption through recycling efforts (e.g. They're Calling on You campaign). All of these approaches have some benefits but also limited success to date.

Boycotting DRC produced coltan, if it can be accurately identified in the first place, brings up many problems in itself. A boycott of all coltan, whether by individual consumers or by corporations, will deny people of the DRC an income that is greatly needed, as well as depriving warlords of their income. As an alternative, tracing the source of the weapons used in conflict and stopping the flow of weapons into the region may be an alternative to stopping the trade of coltan out of the region. The weaponry used in the civil war is not made in the DRC nor in neighbouring African states and this approach may prove more successful at halting conflict.

CONCLUSION

In conclusion, mobile telephony has made one of the biggest improvements to life in Africa in decades. Connectivity enables knowledge, power and ultimately gives the people strength and the ability to act as global citizens on global issues. The rise of the production of mobile telephony and lightweight electronic goods has also contributed to funding one of the bloodiest and longest running civil wars in Africa's history. With an estimated 5 million people killed in the civil war conflicts to date in the DRC, the mining of coltan for militia profit has indirectly had a terrible impact on human life and the environment. Using MRIO analysis helps conceptualise the scale of the problem and allocate a responsibility for deaths along the supply chain of coltan. The research using MRIO analysis to enumerate the social footprint of the coltan supply chain provides a novel quantitative analysis. Future research will include more recent data sets studying the supply chain of coltan, applying this methodology to other social indicators for supply chain management and identifying effective ways to seek environmental justice in the supply chain.

Notes

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CHAPTER 6: THE CONTRIBUTION OF INPUT-OUTPUT ANALYSIS TO UNDERSTANDING IMPACTS OF CONSUMPTION – A REVIEW UPDATE

ABSTRACT

Understanding the life-cycle impacts of consumption is important for consumers, producers and policy makers as they respond to increasing information demands to quantify sustainability impacts. Since 2010 the use of input-output analysis to understand consumption has expanded significantly. In this paper we provide a review of recent applications of input-output analysis and multi-regional input-output analysis as applied to consumption-based accounting. This work builds on two past reviews on this subject, looking at developments since 2010 and future directions. The reviews by Hertwich (2011) and Wiedmann (2009) both reflected on the use of input-output analysis to account for environmental impacts, and in particular carbon dioxide and greenhouse gas emissions. This review demonstrates the broader range of impacts addressed in recent years in a form of quantified sustainability, ranging from environmental and social impacts, to international trade and global supply chains to policy development and assessment. We review methodological advances and look to the future with the advent of virtual laboratory infrastructure to bring users of IOA together from around the world.

Keywords: consumption, input-output analysis, environmental policy, social ecology, big data, quantified sustainability.

1. INTRODUCTION

In 1776 Adam Smith[1] stated that "Consumption is the sole end and purpose of all production", concluding that "… the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer." Even though the world has changed dramatically since and globalisation has increased the physical separation between consumers and producers, there is an inextricable economic link between consumption and production and the first part of Smith's statement is still valid today. It's interpretation, however, has changed in a world that is more concerned with the environmental and social impacts of global economic growth (Costanza et al. 2014). In modern times scholars have directed their attention to the question of who is responsible for these impacts and how the negative impacts can be mitigated. Understanding the life-cycle impacts of consumption is important for consumers, policy makers and increasingly producers as they have to respond to information demands from extended producer responsibility, detailed supply chain analysis and markets.

There exists recent literature on this topic. Hertwich (2011) provided a review of the life-cycle environmental impacts of consumption, including the emissions and resource requirements of final demand by households and government in different countries. Not included in Hertwich's review was Wiedmann's (Wiedmann 2009a) review of the use of multi-regional input-output analysis (MRIOA) to analyse consumption. Wiedmann provided an overview of the methodological features of around 20 studies between 2007 and 2009, focussing on consumption-based accounting (CBA) of greenhouse gas (GHG) emissions and resource consumption and its relevance to policy and decision-making.

Hertwich's review defined consumption (with particular reference to input-output modelling) as the amount of emissions and resource use associated with final of products across households, government, and investment and export categories. Input-output tables are thus very useful when considering consumption because they connect production and consumption activities within an economy through industry sectors to their final demand categories. The association of value added accounts, such as environmental or labour accounts, using the Leontief model enables the allocation of these elements throughout the economy and to final consumption (or demand) by consumers (Hertwich 2011). Often referred to as a top-down approach, input-output analysis (IOA) enables whole upstream supply chains to be analysed in relation to final demand or consumption.

To the authors' knowledge, no further review articles have since been published in the area of using IOA for understanding consumption patterns and their associated impacts. However, the number of publications addressing 'consumption' with 'input-output analysis' has risen sharply, with about 1000 hits for these search terms in Scopus between 2011 and 2013 alone (Figure 1). A recent special issue of the *Journal of Industrial Ecology* (Lifset 2014) highlighted the role of footprint analysis to understand the life-cycle impacts of consumption. However, the special issue did not explicitly focus on the role of IOA. Using the two previous reviews as a baseline, in this paper we account for the most recent developments in the field. Our literature review expands on prior work on two aspects in particular.

[1] Full reference taken from http://www.adamsmith.org/quotes: "Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer." The Wealth Of Nations, Book IV Chapter VIII, v. ii, p. 660, para. 49. First published in 1776.

1) Since 2010 and with the further development of multi-regional input-output databases in particular, the field of IOA has expanded significantly. We provide an update on recent applications of MRIOA aimed at understanding the impacts of consumption.
2) The reviews by Hertwich and Wiedmann reflected a situation where many papers on consumption primarily addressed energy and GHG, rather than a broader range of environmental and other impacts. We review the recent development of the field to include not only more environmental impacts, but also social and economic impacts.

Accordingly, in this review paper we present the use of IOA to further our understanding of consumption impacts, with particular reference to environmental, social and trade impacts, since 2010. Section 2 provides a review of the evolution of input-output (I-O) methodology, covering the extension of modelling capability, availability of big data, and advancements in techniques. Section 3 addresses the application of IOA to consumption studies in a range of fields including environmental extensions, international trade, consumption impacts in developing countries, public services and policy assessment and socially-extended IOA. Section 4 provides a discussion on future directions for IOA and our understanding of consumption and our conclusions.

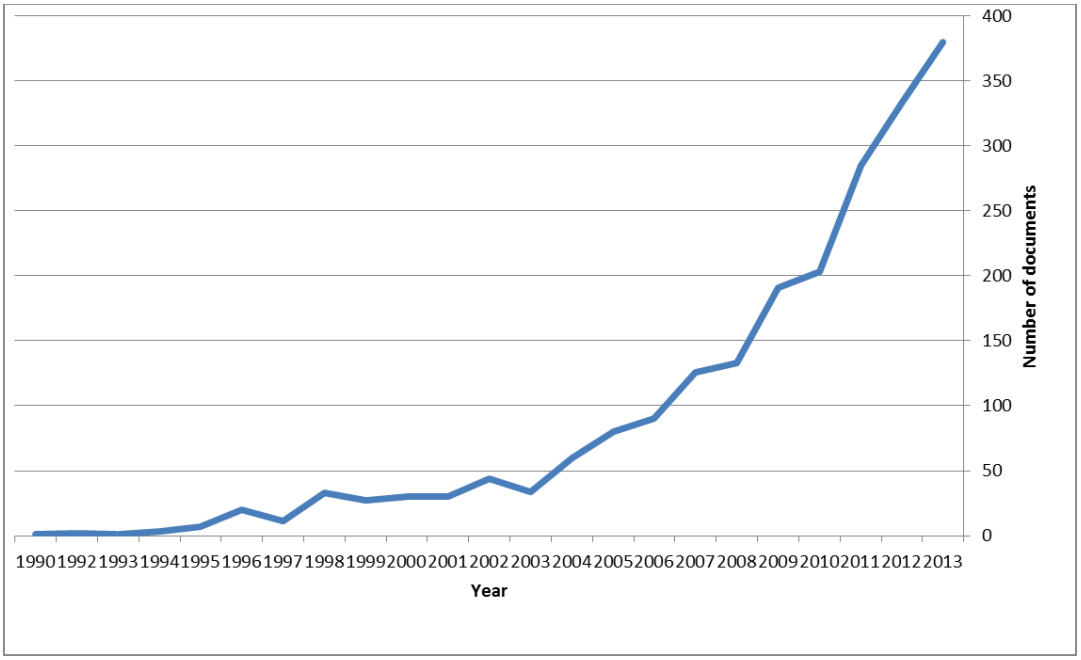

Figure 1: Number of publications found in the Scopus databases when searching for the terms "input-output analysis" AND "consumption" (www.scopus.com, retrieved 13 May 2014).

2. EVOLUTION OF INPUT-OUTPUT METHODOLOGY

Whilst the basic input-output methodology as pertaining to Industrial Ecology applications has not changed fundamentally, there have been a number of innovations with regard to increasing global coverage, resolution, accuracy, analytical techniques and tools. This has led to an impressive increase in the number of policy-relevant applications addressing environmental, economic and social questions.

2.1 EXTENDED MODELLING CAPABILITY AND BIG DATA

A strong driver in this development has been the completion of several global MRIO datasets[2], summarised in a special issue of *Economic Systems Research* (Tukker and Dietzenbacher 2013) and elsewhere (Murray and Lenzen 2013a; Wiedmann et al. 2011b). Consumption modelling using MRIO analysis is in part being driven by the availability of large data sets. Referring to the concept of using large or multiple sets of data to build complex databases of interrelating information, 'big data' are increasingly being relied upon in MRIO. A study of the evolution of big data found that prior to 2008 there was not even a terminological consensus, however a search of ISI Web of Science reveals 94 articles on big data written between the years of 2008 and 2012 (Snijders et al. 2012). The evolution of the use of big data for IOA has influenced the direction of consumption analysis since 2010. The role of big data in LCA was explored by Cooper et al (2013), and given the complementary nature of LCA and IOA in analysis of consumption it is clear that big data has a role to play in IOA too. Hubacek et al (Hubacek et al. 2014) used the concept of 'teleconnecting' consumption with environmental impacts across varied geographies. As referred to by Yu et al (2013b), teleconnections are a convenient way to conceptualise the connectivity of people and places, particularly with respect to consumption. Based on the interrelatedness of climate over great distances, teleconnections in this application refer to dual track of increasing connectivity between people and places, and the simultaneous separation of places of production with consumption (Yu et al. 2013b). Examples of using large data sets to analyse consumption in supply chains include using the GTAP MRIO database with sources such as Food and Agriculture Organisation statistics (FAOstat), World Resource Institute (WRI) database, Eurostat and Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science data (Yu et al. 2013a) and using the Eora MRIO database with the International Labour Organization's LABORSTA database, United Nations System of National Account UNSNA-Official Country database (UNSD 2011), the Standardized World Income Inequality Database (SWIID), the Organization for Economic Co-operation and Development (OCED) and World Bank databases for the Gini index details (McBain and Alsamawi 2014).

Since the last reviews by Wiedmann and Hertwich, available computing power has grown considerably. This has enabled the development of multi-region databases, often global in coverage, containing data for hundreds of countries. Wiedmann attributed the rapid growth of MRIO databases to the increasing need for global analytical capacity in sustainability research, particularly with respect to the globalisation of production and consumption practices (Wiedmann et al. 2011b). Kanemoto et al found that when analysing international trade, particularly with reference to consumption-based carbon emissions of different countries, MRIO analysis should be the preferred methodology over Emissions Embodied in Bilateral Trade (EEBT) (Kanemoto et al. 2011).

Hertwich made reference to the development of MRIOA and key papers at the time of the review, but points out that high sector aggregation using this technique can introduce errors into life-cycle calculations (Hertwich 2011). Wiedmann also highlighted problems found with using MRIOA for CBA including sector aggregation, treatment of the Rest of the World (ROW) region, monetary exchange rates, treatment of trade flow matrices and uncertainties with trade statistics and called for the research community to address this issue (Wiedmann 2009a). The increased political relevance of MRIO studies (see section 3.5) has generally led to intensified scrutiny of the modelling results and several studies have been completed (Wilting 2012) or are underway to understand details of factors that contribute to sensitivity and uncertainty in MRIO models (scheduled for a special issue of *Economic Systems Research* in 2015). The approach of calculating relative standard deviations for each MRIO table element, based on constrained

[2] (Tukker et al. 2013); (Meng et al. 2013); (Lenzen et al. 2013a); (Dietzenbacher et al. 2013a); (Andrew and Peters 2013)

optimisation, has been implemented in the UK-MRIO model (Lenzen et al. 2010) and the global Eora model (Lenzen et al. 2013a).

Industrial ecology applications are now being trialled in an entirely novel computational and collaborative setting called a Virtual Laboratory. The Australian Industrial Ecology Laboratory (IELab) (Lenzen et al. 2014b) uses cloud-computing and a collaborative approach to compiling large-scale MRIO tables that can be tailored by the user to suit specific research questions. The aim of the IELab is to provide researchers with advanced tool, large-scale databases as well as significant RAM in order to conduct Industrial Ecology studies at high sectoral and regional resolution otherwise not achievable on desktop machines. At the time of writing a collaborative research project (http://www.isa.org.usyd.edu.au/mrio/mrio.shtml) existed with the aim of establishing IELab technology at the global level, and establishing the means for regularly updating global MRIO frameworks such as EXIOPOL, Eora and WIOD. This type of project has only become possible due to the ability to manipulate big data sets, and the first results are expected for 2016.

2.2 ADVANCEMENTS IN INPUT-OUTPUT TECHNIQUES

Advances have been made in terms of adding subnational, regional detail to Industrial Ecology studies. A number of subnational MRIO databases have been constructed[3] and used for evaluating impacts of consumption. At times, subnational MRIO tables have been combined with extensive household expenditure surveys or pollutant inventories to yield a detailed picture of embodied resource flows across a nation. For example, two urban hinterland studies (Baynes et al. 2011; Lenzen and Peters 2010) map out the indirect (rural) resource requirements of typical urban households in great geographical detail.

Of increasing importance for assessing the impacts of consumption is the evaluation of supply chains through structural analysis. Hertwich referred to Structural Decomposition Analysis (SDA) in his 2011 work as a means to analyse changes in environmental variables over time in terms of production and consumption (p43). Not included in that review was the paper by (Wood and Lenzen 2009b) who combine SDA and Structural Path Analysis (SPA) into Structural Path Decomposition (SPD). In essence, SPD is an SPA on the series expansion of the Leontief inverse. Within SDA, the contributions to footprints are evaluated for terms such as final demand, resource/pollution intensity and the Leontief inverse. Within SPA, these terms are also evaluated, but in addition the Leontief change term is disaggregated into changes of first-, second-, and etc higher-round supply-chain effects, allowing to identify which order paths contribute most to the change attributable to the production structure. For example, if SPD were applied to a global MRIO study, the supply-chain terms could reveal whether drivers of global environmental impact are predominantly changes in immediate, mostly domestic input-output transactions, or changes in multi-node, potentially international trade relations.

IO frameworks have increasingly been coupled with non-economic, physical data to improve resolution, correct for price variations or introduce additional capability. Ewing et al. (2012), for example, created a detailed account of the mass flow of agricultural, livestock, fishery and forestry products alongside the monetary use account in an MRIO framework. The benefit of such an account is that additional, product-specific attributes such as water use data can be contained in the mass-unit account while maintaining transparency and integrity in the less detailed monetary dataset. This allows for a much more refined calculation of environmental footprints of consuming individual products. The hybrid MRIO model has been applied in

[3] (Cazcarro et al. 2013; Daniels et al. 2011; Escobedo-Cardeñoso and Oosterhaven 2012; Feng et al. 2012; Guan and Hubacek 2007; Jackson and Schwarm 2011; Lenzen 2009; Többen and Kronenberg 2011).

several studies to evaluate different types of consumption footprints for the European Union and individual countries (Steen-Olsen et al. 2012b; Weinzettel et al. 2013; Weinzettel et al. 2014).

Further advances have been made in improving the accuracy of IO models by replacing monetary data (which may be affected by price inhomogeneity) with physical data in hybrid-unit models. Examples are the calculation of raw material consumption (the material footprint) for the European Union (Schoer et al. 2012), inland marine transportation (Ewing et al. 2011) and the disaggregation of the electricity sector in a Chinese input-output model to evaluate the primary energy embodied in Chinese final consumption (Lindner and Guan 2014).

Only since about 2010 have global and subnational MRIO frameworks been adapted to include or utilise process-based, life cycle inventory data to enable hybrid LCA applications. Applications have focussed on the assessment of renewable energy technologies, based on integrated hybrid LCA by linking process data to IO matrices (Acquaye et al. 2012) (Wiedmann et al. 2011c) (Acquaye et al. 2011) or by inserting new sectors derived from process information into the IO tables (Malik et al. 2014; Moran et al. 2014). MRIO-based hybrid LCA represents a significant way forward in IO-assisted LCA, because with increasing globalisation LCA applications will increasingly deal with functional units that draw on inputs sourced from many countries. Only an MRIO model underpinning a hybrid LCA exercise can ensure that country-specific production recipes as well as international trade are being considered during the enumeration of the functional unit's supply chain.

New light on uncertainty analysis in LCA (Imbeault-Tétreault et al. 2013) and IO-assisted LCA (Heijungs and Lenzen 2014) has been cast, showing that analytical approaches using truncated Taylor expansions in order to determine standard deviations of impact measures can be virtually as accurate as Monte-Carlo approaches, but are usually much less time-consuming.

3. APPLICATIONS

This section showcases the breadth of application of IOA to assessing consumption from environmental footprints, to the rapidly expanding area of supply chain analysis and international trade, to policy development and assessment.

3.1 ENVIRONMENTAL EXTENSIONS AND INDICATORS

When considering environmental impacts, Hertwich found that there had been few applications of the IOA methodology to consumption impact studies beyond energy use and GHG emissions (Hertwich 2011). In his analysis of the use of MRIOA to CBA, Wiedmann (Wiedmann 2009a) also found a strong focus on CO_2 and GHG emissions. Whilst energy and GHG emissions are still common consumption impacts studied using IOA, the field has broadened considerably. Environmental footprinting as a technique has gone through a number of cycles, from providing a single number of integrated environmental impacts to a more detailed accounting of a single type of impact (Hoekstra and Wiedmann 2014; Lifset 2014). Footprinting remains a popular use of IOA to evaluate the impacts of consumption. This includes carbon footprints[4], water

[4] (Larsen and Hertwich 2011; Larsen et al. 2012; Wang and Li 2012a, 2012b; Wiedmann and Barrett 2011a; Zhang et al. 2014); (Shigetomi et al. 2014); (Yao et al. 2013); (Ala-Mantila et al. 2013); (Whittlesea and Owen 2012); (Wang and Li 2012b) (Wiedmann and Barrett 2011b); (Berners-Lee et al. 2011); (Nansai et al. 2009)

footprints[5], material footprints[6], biodiversity footprints[7], employment footprints[8] and various other environmental pressures expressed as footprints[9].

Water footprinting has perhaps seen the largest increase in consumption-based IOA applications that investigate the role of trade in virtual water or establish water footprint accounts for regions and consumers in the same way as is being done for GHG emissions (carbon footprints). A recent special issue of *Economic Systems Research* summarised the state of research (Duarte and Yang 2011). Daniels et al. (2011) provided a review of MRIO approaches and water footprints for regional sustainability analysis and water policy. Similar to the developments in carbon footprint accounting there is an ongoing debate about the respective strengths and weaknesses of bottom-up and top-down calculations approaches to water footprinting. Daniels et al. (2011) argued that Environmentally-Extended MRIO (EE-MRIO) is well suited to complement process-based approaches to water footprinting by expanding the supply-chain coverage and by establishing the geography of embodied water. Another innovation in water footprinting is the inclusion of scarcity. Considering the physical flow, it doesn't make sense to add supply-chain contributions of water from Ireland and water from Uzbekistan, the latter being much scarcer (Lenzen et al. 2013c).

Feng et al. (2011a) compared the water footprint of nations based on two IO based top-down approaches, looking at either bilateral trade alone or the full supply chain of consumption, using the MRIO calculus. Country-specific water footprint studies using W-MRIO include studies for the UK (Feng et al. 2011b); (Yu et al. 2010), China (Dong et al. 2013; Feng et al. 2012; Lin et al. 2012; Zhang et al. 2011a; Zhang et al. 2011b; Zhao et al. 2010) and Mexico (López-Morales and Duchin 2011). The studies for China and Mexico use sub-national inter-regional input-output models for China. So does another article that investigates the ecological footprints of consumption in eight regions of China (Zhou and Imura 2011) and CO_2 emissions embodied in trade (Su and Ang 2014).

The first comprehensive and consistent inclusion of carbon, water and ecological footprint indicators in an EE-MRIO framework was described by Galli et al. (2012). The authors argued that combining these overlapping, interacting and complementing indicators in a 'Footprint Family' and one modelling framework is of benefit for decision-making. They tested this integrated framework against some of the main European (and international) policy objectives and outcomes.

Footprint indicators have been combined with an EE-MRIO model (Weinzettel et al. 2011) (Hertwich and Peters 2010) in the project One Planet Economy Network Europe (OPEN:EU) funded by the European Commission. A user-friendly analysis and scenario tool was developed from the model. The EUREAPA tool[10] allows the user to quantitatively unravel global supply chains using a carbon, ecological and water footprint indicator (Roelich et al. 2014). The links

[5] (Cohen and Ramaswami 2014; Feng et al. 2012; Feng et al. 2011a; Huang et al. 2014; Xiao et al. 2011); (Chen et al. 2012);(Chen and Chen 2013); (Dong et al. 2013); (Duarte and Yang 2011); (Daniels et al. 2011); (Feng et al. 2011a); (Feng et al. 2011b); (Yu et al. 2010), (Feng et al. 2012; Lin et al. 2012; Zhang et al. 2011a; Zhang et al. 2011b); (Dong et al. 2013); (López-Morales and Duchin 2011); (Xiao et al. 2011)

[6] (Wiedmann et al. 2013); (Bruckner et al. 2012; Kovanda and Weinzettel 2013; Kovanda et al. 2012; Muñoz et al. 2009; Schoer et al. 2012; Weinzettel and Kovanda 2009, 2011; Wiebe et al. 2012); (Wiedmann et al. 2014).

[7] (Lenzen et al. 2012c).

[8] (Alsamawi et al. 2014b)

[9] (Moran et al. 2013); (Duarte and Yang 2011; Ewing et al. 2012; Galli et al. 2012; Hertwich and Peters 2009; Wiedmann 2009a; Wiedmann 2009b) (Zhou and Imura 2011); (Weinzettel et al. 2011); (Hertwich and Peters 2010).

[10] https://eureapa.net

between the consumption of a product type in one country and its production impacts elsewhere are identified and the top ten sources of greatest impact are displayed. The scenario editor within the tool can be used to explore the environmental pressures associated with changes in population, consumption patterns, production technology or trade over time. Such functionality had not been provided in an EE-MRIO online tool before and the new information is presented in a useful and accessible way.

3.2 RECENT FOCUS AREAS OF CONSUMPTION-RELATED STUDIES

There have been a number of applications in specific research areas related to consumption of which we present two separately – food and cities.

3.2.1 FOOD

Hybrid LCA studies of different diets and food scenarios were conducted in several European countries. Virtanen et al (Virtanen et al. 2011b) use an IO model at the national level and process-based LCA for food portions to calculate the carbon footprint of the whole food life cycle in Finland. The study demonstrates the significance of non-CO_2 emissions and of the consumer phase for the total climate change impact. In Germany, Meier and Christen (Meier and Christen 2012) found that the environmental impacts of typical German diets in 2006 were significantly lower than they were in 1985-1989, especially for vegetarian and vegan diets (with the exception of blue water consumption of these diets due to the contents of nuts and seeds). A study in Australia (Hendrie et al. 2014) found that non-core foods in the average Australian diets accounted for 27% of food-related GHG emissions and that a reduction in non-core foods may be beneficial for both population health and the environment.

A typical Mediterranean diet was found to decrease environmental impacts modestly (2-7% reduction), compared to the average national diet in Italy (Pairotti et al. 2014). A slightly higher reduction of impacts (3-12%) was found for vegetarian diets. The food and beverage sector has been confirmed to be amongst the top three sectors for the consumption of embodied energy by Italian households (Cellura et al. 2011).

Meat consumption is generally confirmed to contribute most to the environmental impacts of food. A pan-European study found that even relatively modest reductions in the meat content of diets can reduce overall impacts by around 8% (Tukker et al. 2011). But how do nutritional and dietary choices by the consumer play out in the food production system worldwide and in terms of associated environmental changes? Such questions have been addressed with dynamic models. Combining IOA with a partial equilibrium model, Wolf et al (2011) find that agricultural production does not change significantly in reaction to reduced food consumption because of a changed trade balance and substitution effects. In a recent study, Springer and Duchin (Springer and Duchin 2014) employ a global MRIO model to analyse future scenarios of food consumption and associated impacts on resources worldwide. Evaluating different scenarios of population, nutrition and agricultural technologies, the authors find that feeding a world population of nine billion people in 2050 sustainably is only possible if diets become less resource-intensive and agricultural productivity improves significantly, especially in Africa. Creating a consumption-based inventory of land use in the US, Costello et al. (Costello et al. 2011) find that processed foods and forest products are the largest users of land. Supply chains of food manufacturing sectors are responsible for large shares of environmental impacts in the US, especially the meat processing sector (except poultry) (Egilmez et al. 2014).

3.2.2 CITIES

IO analysis is increasingly being applied to calculate the environmental footprint from urban consumption. Wright et al (Wright et al. 2011) and Baynes and Wiedmann (Baynes and Wiedmann 2012) summarised the literature on consumption-based accounting at the city scale up to 2011/12. Since then IO-based carbon footprints and related environmental indicators have been estimated for Aveiro, Portugal (Dias et al. 2014); Helsinki, Finland (Ala-Mantila et al. 2013); four Chinese Megacities (Feng et al. 2014); Glasgow (Hermannsson and McIntyre 2014); 434 municipalities in the UK (Minx et al. 2013); Beijing (SDA from a production and consumption perspective) (Liu and Zhang 2012; Wang et al. 2013); the Beijing-Tianjin agglomeration and other regions in China (Yao et al. 2013), all providing new insights into the relationship between urban consumption and lifestyles and tele-connected environmental impacts elsewhere.

In all cases urban household consumption data was used to attribute direct and indirect emissions to the final consumption of city residents. (Wang et al. 2013) present a structural decomposition analysis of Beijing from a production and a consumption perspective. Increasingly, sub-national MRIO tables (Feng et al. 2014; Yao et al. 2013) and even city-level IO tables (Wang et al. 2013) are used for the calculations. Liu and Zhang (2012) derive a physical IO table to study the material metabolism of Beijing. A typical finding for large cities is that of (Feng et al. 2014) who calculated that more than 70% of CO_2 emissions related to the consumption of goods in Beijing, Shanghai and Tianjin occur outside of the city boundary.

3.2.3 INTERNATIONAL TRADE AND GLOBAL SUPPLY CHAINS

One of the fastest growing applications of MRIOA for understanding the global impacts of consumption, as compared to earlier reviews, is in the analysis of global supply chains. Writing initially in 2009, Hertwich stated that assessing international trade by using IOA was the subject of lively debate (Hertwich 2011). As shown in Figure 2, international trade has grown rapidly, with exports of goods and services 49 times greater now than in 1970 (Kanemoto and Murray 2013). The volume of international trade, in terms of intermediate inputs and the final consumption of goods, has tripled since the start of this century alone (Wiebe et al. 2012). As stated by Wiedmann in his 2009 review, "*MRIO-SPA* [structural path analysis] *is ideally suited to extract and prioritise impacts from international commodity chains and to link locations of consumption with hot spots of environmental impacts. MRIO analysis offers many advantages when analysing global supply chains.*" (Wiedmann 2009a). These advantages include the ability to assess direct as well as indirect impacts, avoidance of boundary cut off issues experienced with methods such as LCA (Acquaye et al. 2011) and increasingly the ability to assess not only environmental impacts through the association of satellite accounts (Acquaye et al. 2011; Davis et al. 2011; Feng et al. 2012; Yu et al. 2010) but also assess social impacts through the association of social satellite accounts (Alsamawi et al. 2014b; Alsamawi A. et al. 2014; Moran et al. 2014). Given how useful satellite accounts are for analysing consumption activities in supply chains using MRIOA, a consistent approach to the generation of data is required. To this end, the UN System of Environmental-Economic Accounting – Central Framework (Division 2014) provides a framework for the development of environmental satellite accounts in a consistent manner, and there have been calls for the development of a similar system with respect to social accounts (McBain and Alsamawi 2014). Wiedmann *et al* discuss the versatility of using MRIOA to understand policy implications around consumption, including resource exploitation, ecosystem health, environmental footprint, risk and vulnerability, social cohesion, inequality, poverty, child labour, shared responsibility, global financial crisis (Wiedmann et al. 2011a).

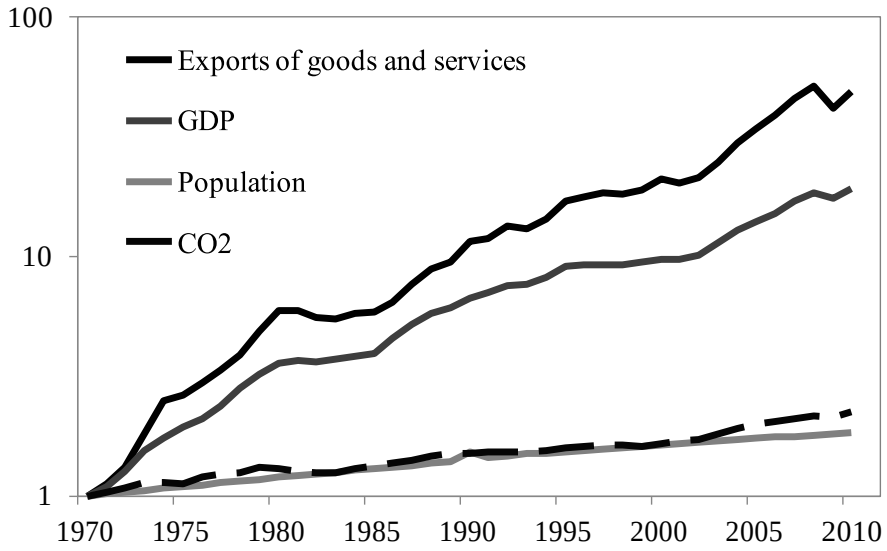

Figure 2: Relative change in exports of goods and services as compared to GDP, world population levels and global CO_2 emissions. Source: (Kanemoto and Murray 2013)

However, a stronger focus has emerged on using IOA to better understand and quantify the impacts of supply chains and international trade. For example, Aviso et al (2011) looked at the water intensity of production via product supply chains. Steen-Olsen et al (2012b) compared three footprints (water, greenhouse gas emissions and land) for three EU countries with a specific focus on environmental pressures caused by international trade, Su and Ang (2014) looked at the energy related CO_2 emissions embodied in trade in inter-regional trade as well as international trade, and Egilmez et al (2014) looked at the environmental footprint of the supply chains of 33 food manufacturing sectors in the USA.

The extent to which consumption in one country has been 'outsourced' to other countries by consuming imported goods and services is well documented by studies of national footprints (Hoekstra 2013; Lenzen et al. 2012c; Peters et al. 2011; Steen-Olsen et al. 2012a; Steen-Olsen et al. 2012b; Weinzettel et al. 2013; Wiedmann et al. 2013). In the UK, for example, around 40% of the CO2 emissions attributable to national consumption lies abroad (Hertwich and Peters 2009) and so does 75% of the water consumption (Hoekstra and Mekonnen 2012). Worldwide, 24% of land use is embedded in international trade (Weinzettel et al. 2013); 22% of water use (Hoekstra and Mekonnen 2012); 26% of CO2 emissions (Peters et al. 2011); and 42% of the raw material consumption (Wiedmann et al. 2013). Thirty per cent of the world's threatened species (Lenzen et al. 2012c), and 32% of the world's scarce water consumption (Lenzen et al. 2013c) can be linked to internationally traded commodities

Affluence and wealth are also drivers for international trade, with several studies finding that international trade has a greater impact outside the consuming country than within. For example, IOA has been used to demonstrate the impact of international trade outside the originating countries borders through the global displacement of land use (Weinzettel et al. 2013); the global loss of biodiversity (Lenzen M et al. 2012b) and the global inequality of income resulting from trade (Alsamawi et al. 2014b). IOA has also been used to analyse other aspects of supply chain analysis, such as the embodied transportation in products (Nealer et al. 2011) and modelling resource supply chains from extraction to production of goods (Duchin and Levine 2013) to mapping the embodied emissions for global supply chains from production to consumption (Skelton et al. 2011). Mapping emissions along global supply chains has been an important development, with other studies including mapping the effects of international

trade on Chinese carbon emissions (Wei et al. 2011); developing whole of supply chain carbon maps (Acquaye et al. 2012); identification of carbon hot spots in supply chains (Acquaye et al. 2011) and comparing emissions associated with production, consumption and international trade (Kanemoto et al. 2011).

3.2.4 UNDERSTANDING CONSUMPTION IMPACTS IN DEVELOPING COUNTRIES

In the first decade of the 2000s the application of CBA was primarily to developed countries and economies. The lack of studies from developing countries was noted in Hertwich's 2011 study. The rapid development and industrialisation of China has raised many questions regarding the environmental impact of the rise of consumption and how the impacts of consumption are coupled with economic growth. Studies contributing to this body of work include GHG emissions and energy footprints (Liu and Ma 2011; Wei et al. 2011; Zhang et al. 2014), water footprints (as covered in Section 3.1), the impacts of residential/household consumption (Liang et al. 2013) and waste generation (Liu and Zhang 2012). Zhang et al (2013) studied consumption (and construction) type emissions using EE-IOA against advances in industrialisation and GDP growth per capita, providing a method for evaluating emissions levels for countries at different stages of development.

Another significant application of the IOA methodology to understanding consumption impacts in development countries has been through consideration of international trade imbalances. Studies such as those considering the income inequality of international trade (Alsamawi et al. 2014b), the biodiversity lost to international trade (Lenzen M et al. 2012b) and the CO2 emissions embodied in international trade in emerging economies in BRICSA (Brazil, Russia, India, China, South Africa and Argentina) (Wiebe et al. 2012) provide a strong focus on the impact of consumption on developing countries and the relative imbalance between the impacts on developing and developed countries.

3.2.5 PUBLIC SERVICES AND POLICY ASSESSMENT

Hertwich found that there had been few attempts to explain or understand the environmental impacts of consumption from public services, especially in a comparative perspective (Hertwich 2011). Governmental reports and policy documents have covered the emergence of IOA for understanding consumption, particularly in relation to sustainable consumption and production (SCP). For example, in 2011 the United Nations Environment Program produced the Global Guidance Principles for Life-cycle Assessment Databases: A Basis for Greener Processes and Products which covered the use of IO tables for modelling more sustainable production as a way of quantifying and communicating the environmental impacts of resource consumption (United Nations Environment Program 2011). The Federal Statistical Office of Germany produced a guide to an extended IO model for energy and GHGs (Mayer and Flachmann 2011). The European Environment Agency produced a technical report in 2013 on the environmental pressures from European Production and Consumption, using EE- IOA (Watson et al. 2013).

Informing climate policy in particular has been a strong policy focus. Recognising the shortfall in international cooperation for global climate change policy, Barrett et al (Barrett et al. 2013) considered the feasibility of using consumption based emissions accounting to measure progress and inform climate change mitigation policy in the UK, (Wiedmann and Barrett 2013) demonstrate the use of EE-MRIO models to provide policy relevant information on GHG emissions and resource consumption in the UK ; and (Barrett and Scott 2012) use an EEIO to assess material efficiency options for reducing GHG emissions in the UK. The footprint family approach to support SCP policies is demonstrated by the program to transform Europe into a One Planet Economy by 2050, where a suite of indictors is used to represent pressure on the

planet (ecological, carbon and water) to inform policy makers and civil society (Galli et al. 2013; Galli et al. 2012).

Not only have governments been producing reports on the use of IOA for consumption analysis, studies have been done on consumption by governments using IOA. For example, studies have analysed the carbon footprint of public services using environmentally extended IOA (Larsen and Hertwich 2011; Larsen et al. 2012) and the carbon footprint of the UK government (Wiedmann and Barrett 2011a). These studies found that government outsourcing activities shifted the impacts of their consumption activities away from their local area and to the upstream supply chain, informing policy that a greater emphasis on supplier performance to manage remote consumption impacts is required.

3.2.6 SOCIAL FOOTPRINTS AND SOCIALLY-EXTENDED IOA

One of the areas of application of IOA that had not been well considered prior to 2010 was the use of socially- extended input-output matrices to study social ecology and social impacts. Although post World War II there had been a focus on using IO to assess social progress, the field did not significantly expand for the next few decades at the expense of the development of E-E IOA (McBain and Alsamawi 2014). Social accounting matrixes, such as that for India, can be used to show interactions between production, income, consumption, and wealth generation (Pal et al. 2012) but are becoming less apparent in academic literature. The UNEP/SETAC guidelines on social LCA and the subsequently developed methodological sheets (Benoit-Norris et al. 2011) contributed to our understanding of consumption through the use of IOA assisted LCA. The use of socially extended MRIO is particularly prevalent for considering the human impacts of consumption from global supply chains. Examples include consideration of the human toll of supplying tantalum to the global marketplace from a conflict zone (Moran et al. 2014) and the impact of commodities produced for US domestic consumption on inequalities in the world system (Prell et al. 2014).

4. DISCUSSION AND CONCLUSION

Any of the methodological innovations discussed in Section 2.1 could trigger significant changes in the outreach of IO-assisted studies of consumption impacts over future years. First and foremost, if Virtual Laboratory infrastructure became more widespread, researchers would be relieved of currently labour- and time-intensive data gathering, because this task would be shared amongst a pool of researchers across multiple institutions. In addition, users ordinarily using only desktop computers would have to their avail high-performance computing resources, including large-scale RAM, multithreaded code, and cloud-computing environments (compare with (Dietzenbacher et al. 2013b). Such infrastructure is able to effectively catalyse research opportunities, however one prerequisite for such leaps forward to happen is user acceptance of new work environments, which in turn will critically depend on how well the new user interfaces package otherwise complicated computational procedures into straightforward workflows (Lenzen et al. 2014a).

Second, if well supported by Virtual Laboratory infrastructure, the compilation and subsequent usage of MRIO frameworks could boost the capability of both footprinting and hybrid LCA, through their enhanced regional resolution and specificity, enabling studies to increasingly take international trade into account. Acceptance of MRIO-based approaches is aided by the fact that MRIOs adhere to the same accounting standards (UN 2009) as their single-region counterparts, so that no new methodological learning or new software would be required.

Third, Virtual Laboratory access could enable operations such as SPA and SPD to become more widespread, because such types of analysis are more meaningful when used in conjunction with sectorally high-resolution IO databases (see for example http://worldmrio.com/biodivmap/). Structural analysis is useful for any organisation wishing to consider environmental and social impact in their procurement decisions.

Finally, new time-saving analytical approaches to traditionally cumbersome and inaccessible uncertainty calculations could facilitate the more widespread complementation of footprint and LCA results with uncertainty information, thus communicating to decision-makers that results are not fixed, accurate numbers, but estimates that need to be taken into account in conjunction with an uncertainty range, thus requiring incorporating probability concepts and strategic hedging into decision-making.

IOA is lighting the way for the future of understanding the impacts of consumption and what *sustainable* consumption (and production) might look like. Through this literature review we have demonstrated the evolution of IOA as a vital tool for understanding industrial ecology and in particular analysing global supply chains and international trade. IOA, with its ability to analyse systems almost without boundaries and utilise global data sets provides for a future of quantified sustainability. Using information resulting from IOA, consumers and producers can develop a better understanding of the many impacts of consumption and how these impacts correlate, with a view towards modelling improved sustainable outcomes for the future.

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CHAPTER 7: A SOCIAL FOOTPRINT OF NATIONS: A COMPARATIVE STUDY OF THE SOCIAL IMPACT OF WORK

ABSTRACT

Work is essential for most people to live a full and complete life. However, far from being an enjoyable pursuit, many people find work places them in vulnerable and even life threatening positions. More than half of the developing world's workers (approximately 1.5 billion people) are classified as being in vulnerable employment, trapped in a cycle where low incomes limit the ability to invest in family and future generation's health and education. No standard footprint methodology has yet been adopted to measure a nation's social impact of work in a similar way to how environmental footprints measure a nation's impact on the environment. Here we develop a method to measure the social footprint of nations by compiling eight indicators, ranging from employment to income to days lost due to accidents. We compare these data for the average worker across developed and developing nations. Our results demonstrate that as countries develop, work domestically has fewer negative social impacts and more benefits to individuals. However, as countries develop they also import more negative social impacts through global trade. This leads to developed nations having two very different social footprints of trade – one for domestic workers and one for international labour embedded in its imports. The development of a replicable and comparable social footprint methodology contributes to our understanding of issues surrounding inequality, the social impact of work, how to measure social impact and how we can communicate complex messages around embedded labour.

SIGNIFICANCE STATEMENT

More than half of the developing world's workers are classified as being in vulnerable employment, trapped in a cycle where low incomes limit the ability to invest in family and future generation's health and education. Empowering policy makers and business to make choices that mitigate some of these impacts through developing and communicating numerically sound information is a priority to address global inequality. Current measurement techniques vary and lessons learned from having divergent methodologies in environmental footprinting indicate that a robust social footprinting methodology is required. We introduce a methodology to create social footprints of nations measuring the social impact of work embedded in global trade. We show that as countries develop, problematic labour impacts are outsourced to developing countries.

Keywords: social footprint, multi-regional input-output analysis, global trade, inequality, embedded labour.

1 INTRODUCTION

Writing in 1910, British journalist and author Arnold Bennett spoke about the newly emerged white collar workforce who worked eight hours a day, five days a week and generally found their work to be something to be endured rather than enjoyed. Taking the case of a Londoner working in an office by way of example, Bennett (1910) observes of the work day:

> *He persists in looking upon those hours from 10 to 6 as 'the day', to which the 10 hours preceding them and the six hours following them are nothing but a prologue and epilogue…. If a man makes two-thirds of his existence subservient to one-third, for which admittedly he has no absolutely feverish zest, how can he hope to live fully and completely? He cannot.*[1]

Work is essential for most people to live a full and complete life. It can be alternatively a source of income, education, friendship, productivity, purpose, fulfilment and even joy. Whilst some might have 'no absolutely feverish zest' for work, studies have shown that full time work resulted in better health than part time or no work, for example (Frech and Damaske 2012); (Zheng and Land 2012). National governments such as that of the UK have even based public health strategies on the link between work, health and wellbeing (Black 2012). The 2014 International Labour Organisation (ILO) *World at Work* report found that countries that made the greatest investment in quality jobs found the greatest improvement in living standards as compared to developing countries that did not focus attention to the quality of jobs despite what we know about the benefits of quality employment. However, far from enjoying work, many people find work places them in vulnerable and even life threatening positions. More than half of the developing world's workers (approximately 1.5 billion people) are classified as being in vulnerable employment, trapped in a cycle where low incomes limit the ability to invest in family and future generation's health and education. Of these, 839 million people in developing countries are classified as living in working poverty, where they earn less than US$2 per day (International Labour Organisation 2014b). There is clearly an argument for work, and quality work in particular, benefitting people.

However increasingly we are hearing more about the dark side of work – excessive work hours, unsafe working conditions, bonded labour, child labour, human trafficking and gross inequality. In fact, some of these issues have become so prevalent in working conditions as to have been named modern slavery. The ILO estimates that up to 21 million people worldwide are victims of forced labour, which generates US $150 billion profits in the private economy each year (International Labour Organisation 2014a). Whilst slavery was outlawed by different nations at different times and at different levels, often the introduction of the Slave Trade Acts (in 1788 in the UK; and in 1794 in the United States) are considered as the starting point for the abolition of slavery. However, the act of working for the benefit purely of others and not the individual has persisted. Alsamawi A. et al. (2014b) created employment 'footprints', showing that the citizens of some nations worked primarily to support the lifestyle of those living in 'Master' nations, creating a master- servant relationship between nations on the basis of international trade. Whilst being recognised as a significant issue, governments have been slow to respond. In 2014 a bill was put before the UK parliament to eradicate modern slavery in UK operations, although at the time of writing the changes to the Companies Act would not include supply chains extending beyond the UK. In 2016 the European Union is likely to enact new laws enforcing companies to report on human rights in their business relationships (Mason 2014).

[1] Arnold Bennet, *How to Live on 24 Hours a Day*, Chapter IV. http://www.gutenberg.org/ebooks/2274 Accessed 5/6/14

Why should we care? Other than personal concern, the impact of business on people is also affecting inequality. The charity Oxfam released a report on global inequality in 2014, attributing the richest 85 people in the world with holding as much wealth as the bottom half of the world's population (Fuentes-Nieva and Galasso 2014). When speaking about the concept of inclusive capitalism, Christine LaGarde, the Head of the International Monetary Fund, said:

> *A greater concentration of wealth could—if unchecked—even undermine the principles of meritocracy and democracy. It could undermine the principle of equal rights proclaimed in the 1948 Universal Declaration of Human Rights.*[2]

French economist Thomas Piketty (2014) argues in his book, *Capital in the 21st Century* that there is rising inequality in the global distribution of wealth, based on his study of wealth and income data from the USA, Britain and France. The book focuses on the role of work and income to generate wealth versus the rate of return on capital. Piketty concludes that the trend towards inequality is unlikely to reverse based on current economic policies adopted across the globe. Published in French in 2013 and English in 2014, the book shot to the bestsellers list in many countries. Work, inequality and social impact are becoming key interests for social researchers, economists, politicians, policy makers and even the general public.

The social contract is being challenged. This is not surprising given that it relies on a seventeenth century understanding that the self-interest of rational man ensures we willingly exchange some of our freedoms in order to enjoy the benefits of whatever political and economic system we, or rather rational man, has tacitly agreed to (Hobbes, in Macpherson, 1985). Rational man is coming under scrutiny, not only on gender equity grounds but also on racial grounds (Friend, 2004). The premise of this tacit agreement between Western governments and their elite, mainly male power-brokers is being questioned. The pact wasn't designed to include women, the poor and the disenfranchised, who were not considered capable of higher-order (rational) thinking, no matter where in the world they lived. This exclusion from higher-order thinking also had repercussions for what could be considered an individual's needs. Maslow's hierarchy of needs implied that those suffering such inequality that their basic needs were barely satisfied were incapable of higher order thinking thus legitimising the distribution of power in favour of the already powerful (Jackson, Jager & Stagl, 2004). Echoes of this still linger. Now it seems the needs of the developed world are consuming the outputs of the developing world (Alsamawi et al, 2013). Globalisation has proved unable to tackle inequality and in some cases has exacerbated it (International Monetary Fund, 2007; Dreher & Gaston, 2008). The needs of vulnerable workers in the developing world seem to be stuck at the bottom of Maslow's hierarchy unseen and unheard by some of the world's largest corporations who knowingly or unknowingly exploit them (Bangladesh All Party Parliamentary Group, 2013). Now, thanks in some part to the power of the media their voices are beginning to be heard. Our research supports those who work to amplify the sound and provoke action on behalf of workers everywhere who suffer gross inequality.

To the authors' knowledge, although some individual indicators have previously been explored no suite of indicators has been adopted to measure a nation's social impact of work. This paper presents an approach to compiling a suite of indictors as a social footprint, measuring eight dimensions of social impact for the average worker, and comparing this across the globe. In this paper we will look at the social footprint of labour for 20 countries, comparing different aspects of labour. In Section 2 we provide a review of social metrics and social footprinting. In section 3 we outline the indicators for our social footprint. In section 4 we discuss the methodology used

[2] Economic Inclusion and Financial Integrity—an Address to the Conference on Inclusive Capitalism by Christine Lagarde, Managing Director, International Monetary Fund, London, May 27, 2014. https://www.imf.org/external/np/speeches/2014/052714.htm

for this study and we review the results found. In section 5 we provide a discussion on the results and future applications, and in section 6 we draw conclusions.

2 REVIEW OF SOCIAL FOOTPRINTING AND SOCIAL METRICS

2.1 SOCIAL INDICATORS AND METRICS

Many indicators of social impact and social progress have been developed over the past 50 years, particularly as alternatives to economic indicators such as Gross Domestic Product (GDP) or measures of subjective wellbeing. For example, a 2013 study showed that although GDP has steadily increased since 1950, life satisfaction (as measured by the Genuine Progress Indicator) has not, and indeed it flattened out in the late 1970s and has not recovered (Kubiszewski et al. 2013). The indicators and metrics attempt to demonstrate, usually as an agglomeration of indicators, either societal progress by country or personal (subjective) wellbeing. Examples of societal wellbeing indices that compare social wellness and progress between countries include the Human Development Index, the OECD Better Life Index, the Well Being of Nations and the National Wellbeing Index. Indices that compare year-on-year country progress include the Australian Unity Well-being Index, the Canadian Index of Well-being and Gross National Happiness. Table S1 in the supplementary information to the paper by Costanza et al (2014) provides a good summary of alternative national indicators of welfare and wellbeing.

Taking a more detailed look at these indices, one of the earliest composite well-being indicators is Bhutan's Gross National Happiness (GNH) indicator. Established in 1972, it measures progress against nine domains (psychological wellbeing, time use, community vitality, cultural diversity, ecological resilience, living standard, health, education, good governance). Employment is not one of the overarching domains, although it is covered within Time Use. The GNH indicator recognises that wellbeing requires a balance between paid work, unpaid work and leisure time, and thus respects a limit of eight hours of work per day, including unpaid work such as child-care and voluntary work. Those who work over eight hours a day are identified for the purposes of the GNH indicator as time deprived (Ura et al. 2012). In a similar way, the European Working Time Directive[3] aims to limit working time, to protect people's health and safety. EU directive also limits people to work less than 35 hours a week, or just under eight hours per day. Many indicators and statistics are collected to monitor and demonstrate the social impacts of the workplace. Datasets from the International Labour Organisation[4] in particular provide data on the many dimensions of the social impact of work on people, including LABORSTA (database of labour statistics up until 2008), ILOSTAT (providing statistics on over 100 indicators) which exist to show when there are negative impacts within the workplace.

To develop a better understanding of social impacts in trade and development, an EU study analysed the social risk profile of EU-27 trade regarding trading partners in 2010. This research covered five thematic areas: Labour Rights and Decent Work; Health and Safety; Human Rights; Governance; and Community Infrastructure (Pelletier et al. 2013). The EU research was in part in recognition that the EU's external policies must respect the '*principles of democracy, the rule of law, the universality and indivisibility of human rights and fundamental freedoms, respect for*

3 Directive 2003/88/EC of the European Parliament and of the Council of 4 November 2003 concerning certain aspects of the organisation of working time http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0088:EN:HTML

4 http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm

human dignity, the principles of equality and solidarity, and respect for the principles of the United Nations Charter and international law' (EC 2008[5]). The thematic areas identified in the EU study aligned with the thematic areas of the Social Hotspot Data base.

The Social Hotspot database[6] uses the primary social impact measurement tools available at an international level - the UNEP/SETAC Guidelines for Social Life Cycle Assessment (UNEP/SETAC 2009), the ISO 26000 Guidelines for Social Responsibility (ISO 2010), the Global Reporting Initiative (GRI) Guidelines and the Global Social Compliance Programme Reference tools (Benoit-Norris et al. 2012). Figure 1 presents a social hotspot index for five of the developing economies considered in our study – Brazil, China, India, Russian Federation, Madagascar, three of which (China, India and Madagascar) have been identified as net exporters of labour (Alsamawi A. et al. 2014b. Table 2). Figure 1 was created using the Social Hotspot database only, for comparative use with the MRIOA footprint developed in this paper. Each circle represents the proportional contribution of labour rights and decent work for the food production industry (vegetables, fruits and nuts) in that country as calculated by social LCA. The map shows, for example, that labour rights and decent work is an issue for all of these countries, and health and safety is a significant concern in Brazil and India. Using the social LCA methodology, the contributing themes within each category are shown for the social impact within that country (domestic labour). This differs for the MRIOA footprinting methodology, where the footprint is calculated based on both the domestic labour from within that country, as well as the imported labour from upstream in the production chain to provide a social footprint. If we draw an analogy with carbon footprinting and the definitions drawn for scopes 1, 2 and 3 within the Greenhouse Gas Protocol[7] , the social footprint calculated in this paper considers the domestic production (scopes 1 and 2) as well as the value chain production (scope 3). The two methods, often referred to as top down and bottom up analysis, can be used in conjunction to provide a detailed assessment. Indeed MRIOA can be used in conjunction with the Social Hotspots database through the GTAP MRIO databases (Benoit-Norris et al. 2012). Further discussion on how social LCA and MRIOA can be used in together is provided in Section 5.1.

[5] EC. 2008a. Consolidated Version of the Treaty on the Functioning of the European Union. Official Journal of the EU C115: 47-199.
[6] www.socialhotspot.org
[7] http://www.ghgprotocol.org/

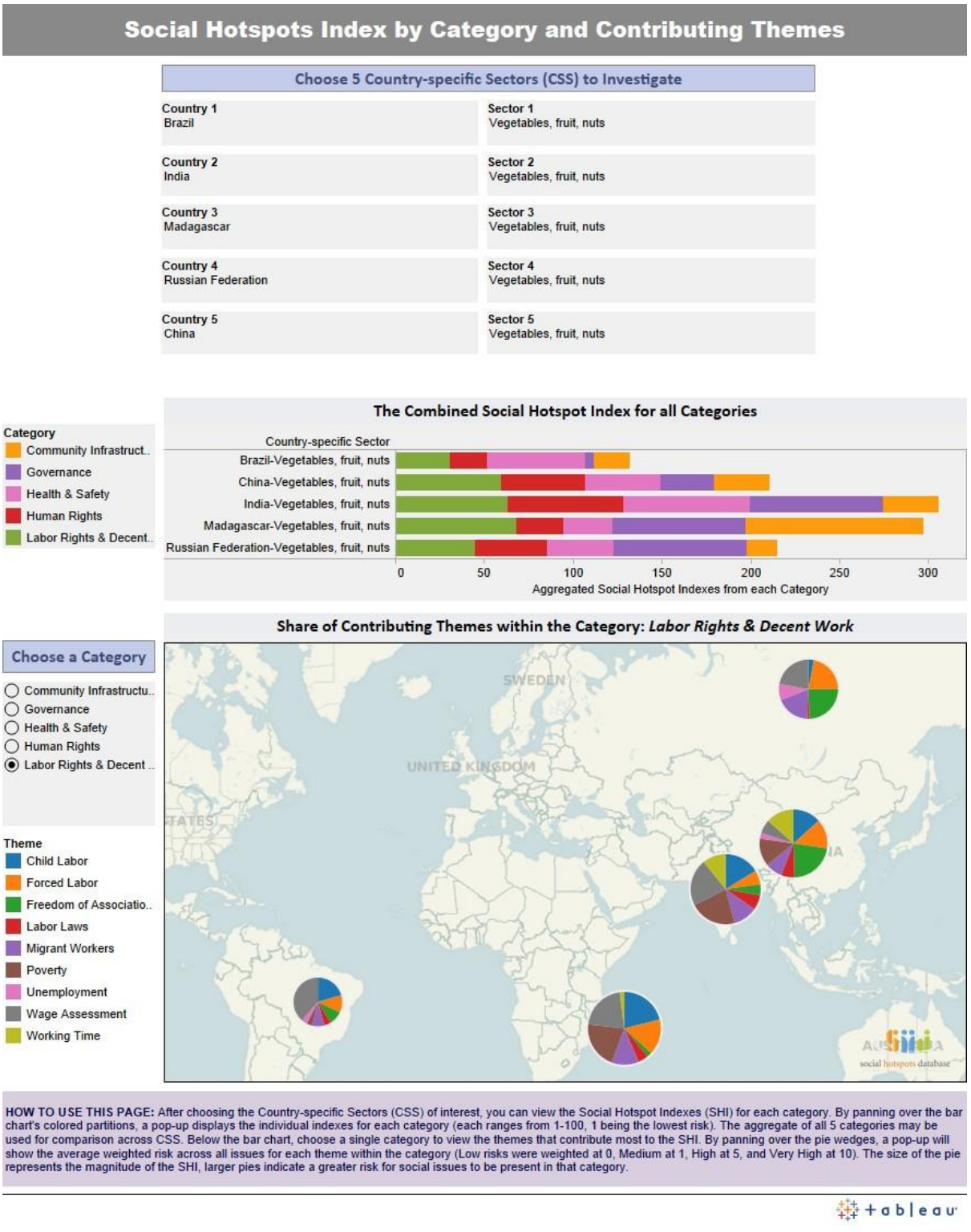

Figure 1: Social Hotspots for Developing Countries in Agricultural Sectors.

Source: Social Hotspot Database Index, Accessed 01/08/14

2.2 FOOTPRINTING HISTORY AND METHODOLOGY

Footprinting is a well-established quantitative technique that has been applied to a number of environmental issues as a method for weighting and aggregating impacts. Van den Bergh and Grazi (2014) looked at the evolution of the ecological footprint as a concept, starting with the paper by Wackernagel and Rees (1996) and gaining momentum over the intervening years, with over 500 journal articles on ecological footprints listed in ISI Web of Knowledge and 32 000 hits in Google Scholar. The term 'footprint' was popularized in the arena of environmental sciences with Rees' (1992) argument on the 'ecological footprint' of cities. Matured later with Wackernagel, it was presented as the amount of land and water ecosystems required to support the 'load' of urban populations, meaning the provision of resources and the assimilation of waste (Rees and Wackernagel 1996).[8] Outside of academia, organisations such as the Global Footprint Network (GFN) have popularised the idea of ecological footprints as a way of demonstrating the impact of human activities on the environment, and whether as individuals or countries we fit within the capacity Earth has to offer. The concept has been developed to the current estimate of required bioproductive area, encompassing croplands and grazing lands, fishing grounds, forest, CO_2 uptake area ('carbon footprint'), and built-in land; and it is now calculated for individual lifestyles, businesses, cities, nations and the entire human population (GFN 2014).

Methodologically, environmental footprints consist of accounts of physical flows, often being time demanding and data limited. Then, Bicknell et al. (1998) proposed their estimation via Input—Output Analysis (IOA); that is, Leontief's (1936) macroeconomic model precisely designed for the evaluation of *total* impacts of economic production/consumption. By then, IOA had already been combined with physical data in order to evaluate social and environmental effects, e.g. employment (Leontief, 1982), air pollution (Leontief and Ford, 1972), and total energy requirements (Bullard, Penner and Pilati, 1978). In view of this operational advantage, environmental footprint accounts have increasingly been adopting input–output frameworks (see Lenzen and Murray, 2001; Hubacek and Gilijum, 2003; Munksgaard et al., 2005; Wiedmann et al., 2006; Ewing et al., 2012; among others). Social footprints, however, have not yet explored this fully.[9] The reason for such lagging development may have been data inaccessibility. However, the emergence of national and international statistical databases, compiling information on production-related social issues (examples provided in the Methodology) makes this advance now feasible. The combination of available big data sets with MRIOA settings, such as the WIOD, EXIOBASE and Eora, sets the path to a new era of social footprint indicators that can keep up with the economic complexities of today (Tukker and Dietzenbacher 2013).

Given its rising popularity among researchers, policy-makers and the public as a measure of ecological burden, other environmental indicators adopted the term footprint, with the water footprint (Chapagain and Hoekstra, 2004) and the carbon footprint among the most popular ones.[10] Application of footprinting methodologies using IOA and multi-regional input-output analysis (MRIOA) includes water footprinting, carbon footprinting, materials footprinting, biodiversity footprinting and employment footprints (McBain et al. 2014). There have also been MRIOA studies on developing a 'footprint family' for ecological, water and carbon footprinting

[8] This concept may had been influenced by the earlier works of Borgstrom (1969) who talked about 'ghost acreages' to describe the additional agriculture and fishing grounds that some countries where using to support their populations, and Vitousek et al. (1986) who estimated the human appropriation of the planet's net primary production, among others.

[9] There has been, though, suggestions to combine Social Life Cycle Assessments with IOA (see Hutchins and Sutherland, 2008; and SHD, 2014), which would be akin to estimating commodity-level footprints of the given social issues evaluated.

[10] There are several definitions of 'carbon footprint' (see Wiedmann and Minx, 2008), which differ significantly from the original 'carbon footprint' component of the 'ecological footprint' (GFN, 2014).

(Galli et al. 2013; Galli et al. 2012). Although the examples outlined above use input-output analysis, there exists numerous methodologies for conducting footprint calculations, and the lack of a single comparable methodology weakens the value of the tool. Academic debate regarding what constitutes a footprint and the validity of the numbers used continues. In particular, the key concerns about the footprinting methodology include translating environmental impacts into a single unit (such as global hectares) to enable comparison, the aggregation of different impacts and the hypothetical nature of using more than one planet (Blomqvist et al. 2013; van den Bergh and Grazi 2014). To allay these concerns, the methodology used in this paper does not seek to create one footprint number using a single unit or aggregation of impacts, but instead presents an array of indicators in their basic units of measurement (see Sections 3 and 4) as has been demonstrated with carbon and water footprints.

As demonstrated above, the term 'footprint' is applied to a number of different applications, without necessarily having consistency in methodology. In a recent speech, comparison was drawn between the evolution of the environmental movement and our environmental understanding with our knowledge of the finance and inequality:

> *"We can draw some parallels here with our expanding environmental consciousness… By comparison, the equivalent kind of awareness in the financial sector—the idea that private misbehavior can have a broader social cost—is only in its early stages. It is akin to the initial period of environmental consciousness, which focused on the banning of lead from petroleum products. Just as we have a long way to go to reduce our carbon footprint, we have an even longer way to go to reduce our "financial footprint"*.[11]

The methodology behind the use of existing 'social footprints' and 'economic footprints' remains loosely defined and is rarely used (see Čuček et al. 2012). As a result of this heterogeneous collection of 'footprint indicators', up to now "there is no standard and clear definition of [what is] a 'footprint'" (Ibid, p. 10). Nevertheless, we may argue that a main aim of footprints is the accounting of *total* (direct and indirect) burdens linked to a given economic activity.[12] Such burdens are usually calculated for different economic commodities, and said to be embodied or embedded in them.[13] These embedded burdens are then aggregated so as to describe the impact of businesses or economic sectors, and following the aim of the original footprint concept, they are reflected upon the consumers of such commodities (e.g. consumer countries' footprints). Several applications of different methodologies have been made, including looking at the employment footprint of nations (Alsamawi A. et al. 2014b); calculating the human footprint on biodiversity (Burton et al. 2014); using a human footprint map for species conservation (Di Marco et al. 2013), the footprint of culture and identity (Minnaert 2014) and using a social footprint to manage corporate sustainability (McElroy and van Engelen 2012). Likewise, Gómez-Paredes et al. (2014) have explored the use of detail labour data and IOA for the calculation of Indian commodities' labour footprints, as means to assess embodied violations of international labour rights and principles, along entire production chains.

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[11] *Economic Inclusion and Financial Integrity—an Address to the Conference on Inclusive Capitalism* by Christine Lagarde, Managing Director, International Monetary Fund, London, May 27, 2014. https://www.imf.org/external/np/speeches/2014/052714.htm

[12] It must be noted that not all the so-called 'footprint indicators' fit this logic, e.g. the 'corruption footprint' or the 'job footprint' (for a brief description of these and other see Čuček, Klemeš and Kravanja, 2012).

[13] 'Commodity footprints' are often the product of Life Cycle Assessments (e.g. Huijbregts et al. 2008; Jefferies et al., 2012).

If we examine the concept of a social footprint further, what is the maximum assimilative capacity of humans? Is it the limit of our population size (which is, in fact, renewable and changeable)? Is it the number of hours a day that a person can work (maximum of 24 or the ideal of eight) or lifespan (which again varies from country to country, and even between genders)? Or is it related to how a person can live life in a happy and just way? Although not a social footprint, the GFN suggests that we need to consider the ecological footprint of an individual (estimated to be 1.8 global hectares per person) combined with a Human Development Index (referred to above) of above 0.8 to have sustainable human development where people can live fulfilling lives without environmental degradation[14]. This contrasts with Bravo's review of the Human Sustainable Development Index which combines the three socio-economic aspects of the Human Development Index (life expectancy at birth, education and income) with an environmental dimension of per capita CO2 emissions (Bravo 2014). The study following outlines the calculation of a social footprint using MRIOA. In this case study, we will use the MRIOA approach to footprinting, and further address questions around this use of footprinting methodology such as additivity and proportionality in the methodology section.

The use of satellite accounts for special purposes in input-output analysis, such as measuring health or environmental impacts, is outlined in the System of National Accounts (United Nations Statistics Division 2008, Chapter 29). Different approaches to assessing social impacts using LCA-MRIO analysis have been used, such as by Benoit-Norris et al (2011) and Rugani et al (2012). Studies linking MRIOA and social impacts are emerging particularly in relation to inequality between global trading partners (Alsamawi A. et al. 2014b; Prell et al. 2014) and assessing product supply chains using the GTAP MRIO database and associated Social Hotspot Database (Benoit-Norris et al. 2012). There are many benefits of using MRIOA for supply chain analysis. The ability to trace millions of supply chains throughout the world has come about through the painstaking creation of detailed MRIO databases based on national economic accounts. Accounts holding detailed social information as they relate to national economic accounts (social satellite accounts) are being developed through other data sources such as the World Bank, World Health Organisation, International Labour Organisation. To trace these supply chains through economic data without the use of MRIOA would be almost impossible, and certainly very time consuming. The scope provided by MRIOA is very large. Using economic data can provide rigor to the process of understanding the social impacts of global trade.

3 CASE STUDY – THE SOCIAL FOOTPRINT OF WORK

3.1 BACKGROUND

All goods and services consumed have a social input. Just as Leontief found that producing a car had an input of pollution, producing a car also has an input of labour. Sometimes that input is local or domestic (the person who made your cup of coffee this morning, for example, who is living and working in the same country as you) and sometimes the labour is imported or embedded within a product (the person who grew the coffee in another country). An ILO report into the World of Work in 2014 found that, "… *economic growth is not sustainable when it is based on poor and unsafe working conditions, suppressed wages and rising working poverty and inequalities*."(International Labour Organisation 2014b). This paper presents a social footprint of consumption for 10 developed and ten developing nations. The consumption consists of both the labour inputs and impacts of people working for domestic consumption, and the imported labour inputs and impacts through the consumption of goods produced internationally. This is similar to how a carbon footprint works, where a carbon footprint looks at domestic production

[14] http://www.footprintnetwork.org/en/index.php/GFN/page/fighting_poverty_our_human_development_initiative/ Accessed 3/7/14

of carbon dioxide emissions, plus those imported to a country embodied in goods and services for local consumption.

3.2 METHODOLOGY

In this paper, the global social footprints of labour are calculated by using MRIO tables. Basic input output theory and extended input-output analysis, as applied in this case study, are described in the paper by Alsamawi A. et al. (2014b) and will not be repeated here for want of space. This study extends previous work on calculating some of the indirect social impacts of nations (Alsamawi A. et al. 2014a, 2014b; Alsamawi A. et al. 2014c; McBain and Alsamawi 2014) by combining multiple satellite accounts to develop a more complex and complete social footprint of work. We created nine satellite accounts, $\mathbf{Q_x}$, which represent the economy wide social accounting identity. The analysis was run using 187 countries and over 15 000 sectors from the EORA MRIO database (Lenzen et al. 2013) using the Leontief demand-pull model, which interprets **Q** as the total social inputs needed to fulfil the final demand, or the social footprint. The satellite accounts are employment ($\mathbf{Q_{emp}}$) and income ($\mathbf{Q_{inc}}$) as calculated in the footprints in (Alsamawi A. et al. 2014b), fatal accidents ($\mathbf{Q_{fa}}$), non-fatal accidents ($\mathbf{Q_{nfa}}$), days lost ($\mathbf{Q_{dl}}$) and wages lost ($\mathbf{Q_w}$), for economic sectors as calculated in health and safety footprints in (Alsamawi A. et al. 2014a), inequality ($\mathbf{Q_{ineq}}$) as calculated in the inequality footprint in (Alsamawi A. et al. 2014c). In addition, we used the same method as that used in (Alsamawi A. et al. 2014a, 2014b) to calculate for the first time the unemployment ($\mathbf{Q_{unemp}}$) and strikes and lockouts ($\mathbf{Q_{str}}$) satellite accounts.

Various databases from different resources were incorporated in this work, to make use of MRIOA's ability to work with big data. Our data were based on the International Labour Organization's LABORSTA database (ILO 2012), the United Nations System of National Account UNSNA-Official Country database (UNSD 2011) for employment data; the Standardized World Income Inequality Database (SWIID) version 3.1 (Solt, 2009), the OCED database (http://stats.oecd.org/) and the Gini index database from the World Bank (http://data.worldbank.org/) for before and after tax income and inequality data; the Asean Occupational Safety and Health Network (http://www.aseanoshnet.org/) for accidents, strikes and lockouts; and the Eora Multi-Regional Input-Output (MRIO) database ((Eora 2012; Lenzen et al. 2012a; Lenzen et al. 2012b) for global inter-industry transactions data.

3.3 LIMITATIONS OF THE MRIOA METHODOLOGY FOR FOOTPRINTING

Using static input-output techniques for footprinting exercises requires making a number of assumptions. Firstly, the constancy of the coefficients in the direct requirements and final demand matrices implies a fixed production and consumption recipe; prices have no influence on producers and consumers alike in choosing their purchases. Secondly, and this is a consequence of the fixed production recipe, Leontief's traditional demand-pull model of the economy assumes proportionality: a doubling of consumption will require a doubling of production, there are no economies of scale, there is no slack in production factors. For more details, see (Miller and Blair 2010). Ultimately, this means that strictly speaking, static IO multipliers and footprints derived thereof have to be interpreted in an ex-post perspective, i.e. as relationships that have played out in the past, and that do not necessarily imply the same cause-and-effect chains in the future. In order to enable future projections, models have traditionally gone beyond the simple static IO mechanism, for example in choice-of-technology models (Duchin and Levine 2011), or the widespread computable general equilibrium (CGE) models ((Rose 1995)). LCA practitioners are also moving towards incorporating more dynamic effects, for example in consequential LCA(Earles and Halog 2011; Finnveden et al. 2009; Weidema 1993).

Another methodological issue in social footprinting is the selection of indicators. Social indicator databases include estimates on gender participation, literacy, and health, that are not readily fit for integration into an (MR)IO framework. This is because first, some of those indicators do not allow allocation of values across impact-causing industries, and second, respective quantity is not additive. The latter point means that it does not make sense to add percentages of literacy, percentages of child deaths, one can only add absolute numbers. This requirement is important in IO analysis, because the Leontief inversion essentially adds up contributions from numerous supply chains. Therefore, only additive quantities can be integrated.

There are limitations to the use of MRIOA for footprinting or global supply chain analysis, which should be understood for the interpretation of results. Limitations of input-output analysis are well understood. For example, if a business understands its size in proportion to the industry sector, it can estimate responsibility proportionally for the chosen indicator. However, if a business does not behave in an average manner (e.g. it uses only recycled material inputs to production) the results will need to be adjusted accordingly. IOA is based on macroeconomic data, collected in accordance with the SNA (United Nations Statistics Division 2009). A nation's accounts depend on that nation being able to accurately collate data relating to labour, employment, income, taxes, trade and even population. However, where a country has a significant underground economy or a population employed in non-paid work (eg domestic labour, subsistence farming), the SNA is unable to account for that economic activity (Waring 1988). Further discussions on IO analysis limitations and strengths in general such as sector averages, uncertainties of data, scope and double counting can be found in texts such as by Murray and Wood (2010). Further details regarding the data quality of the Eora MRIO tables, including data optimisation, standard deviation settings and the confidence of UN Main Aggregates and Official Country Data and UN Comtrade data can be found in Lenzen et al (2012).

4. RESULTS

The study analysed data from 187 countries, across 9 indicators – Employment (people x millions), Income (US$ x billions), Fatal workplace accidents (people x thousands), Non-fatal workplace accidents (people x millions), Days Lost due to workplace injury (days x millions), Wages Lost due to workplace injury (US$ x millions), Unemployment (people x millions) and Strikes and Lockouts (number of events). Figures 2 and 3a and 3b illustrate the footprint results.

The results show that there is a similarity in the social footprint of work in developed nations, but there is a great variability in the footprint for developing nations. The countries shown in Figure 2 were chosen out of the 187 countries analysed as representatives for developed and developing nations. On the right hand side of Figure 2, we display the countries with developed economies. In general, these countries import or consume as much labour as they use domestically, which is why the two lines (red and blue) are very close in size and shape. This graph highlights that the social impacts of consumption in these countries are shared almost equally between the residents of the developed country and by producers in non-resident countries (often developing countries). By contrast, the developing countries shown on the left hand side have larger domestic footprints than import footprints because they represent the world's producers. This relationship was explained in Alsamawi et al's paper on trade Master and Servant relationships (Alsamawi A. et al. 2014b). The countries on the left hand side of Figure 2 also represent the rapidly developing BRIC countries (Brazil, Russia, India and China). Madagascar was included as a developing country because 70% of the population works for the

export market (Alsamawi A. et al. 2014b) and hence it has a small domestic footprint but contributes significantly to the global imports footprints, particularly for countries like France. Figures 3a and 3b represent the total social footprint of work for developing (3a) and developed (3b) nations. These plots shows a multiplier for a given country (m_i) that has been normalised to its final demand

(FD_i), $m_i = \frac{FPi}{FDi}$ where FPi is the total footprints (domestic + import) of the country *i.* The polygon represented in Figures 3a and b show the relative total social footprint of work, where a footprint equal to one represents the worldwide average of all countries. Otherwise stated, the ratio (or the results) m_i is the world average. In these figures, both the size and the shape of the total footprints can be compared and contrasted. In the developed countries (Figure 3b) we see a broad similarity of shape, with a positive social impact skew towards high employment, income and wages lost (where wages lost represents the presence of compensation for sickness or injury). In the developing countries we see a variety of footprint shapes, with a general skew towards negative social impacts such as fatalities, unemployment and non-fatal accidents (for example, see China, India and Madagascar).

Note should be made that two of the countries depicted in Figures 2 and 3, China and Madagascar, do not have any recorded Strikes and Lockouts data. Although an extrapolated data point has been included, it cannot be interpreted as a low number of strikes and lockouts (whether due to good employment laws or bad recording of figures). Of the developed countries, Republic of Korea, Japan, Saudi Arabia and the US all have dips for strikes and lockouts. This represents a lack of worker rights to strike rather than a low rate of strikes due to high worker satisfaction. An interesting contrast exists with Argentina and India, where there are a relatively high number of Strikes and Lockouts, higher than all of the developed countries excepting Italy. This represents the worker ability to strike and the ability to lobby for better pay or conditions.

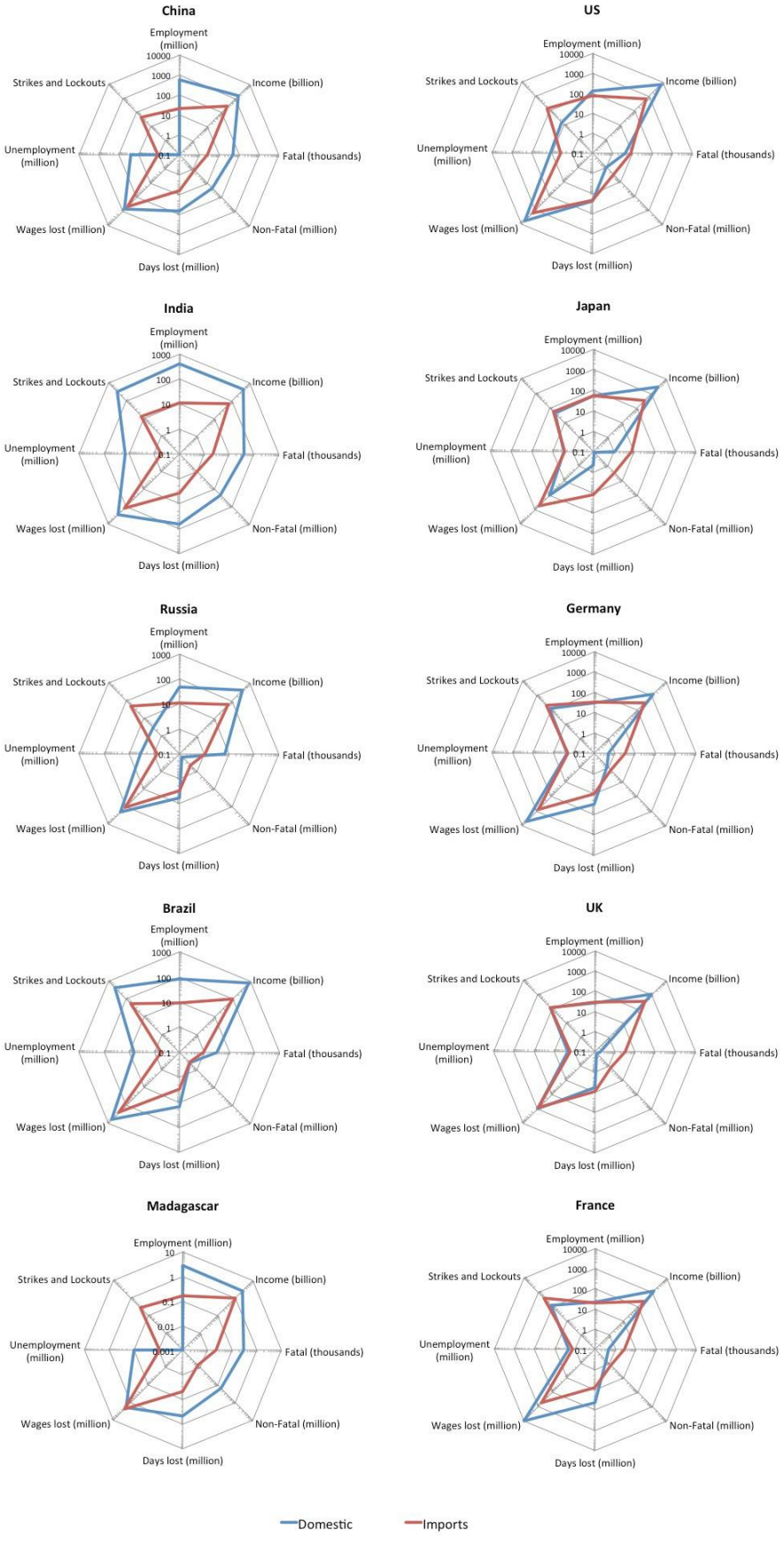

Figure 2: The Social Footprint of Work: Domestic and Imported Social Footprint

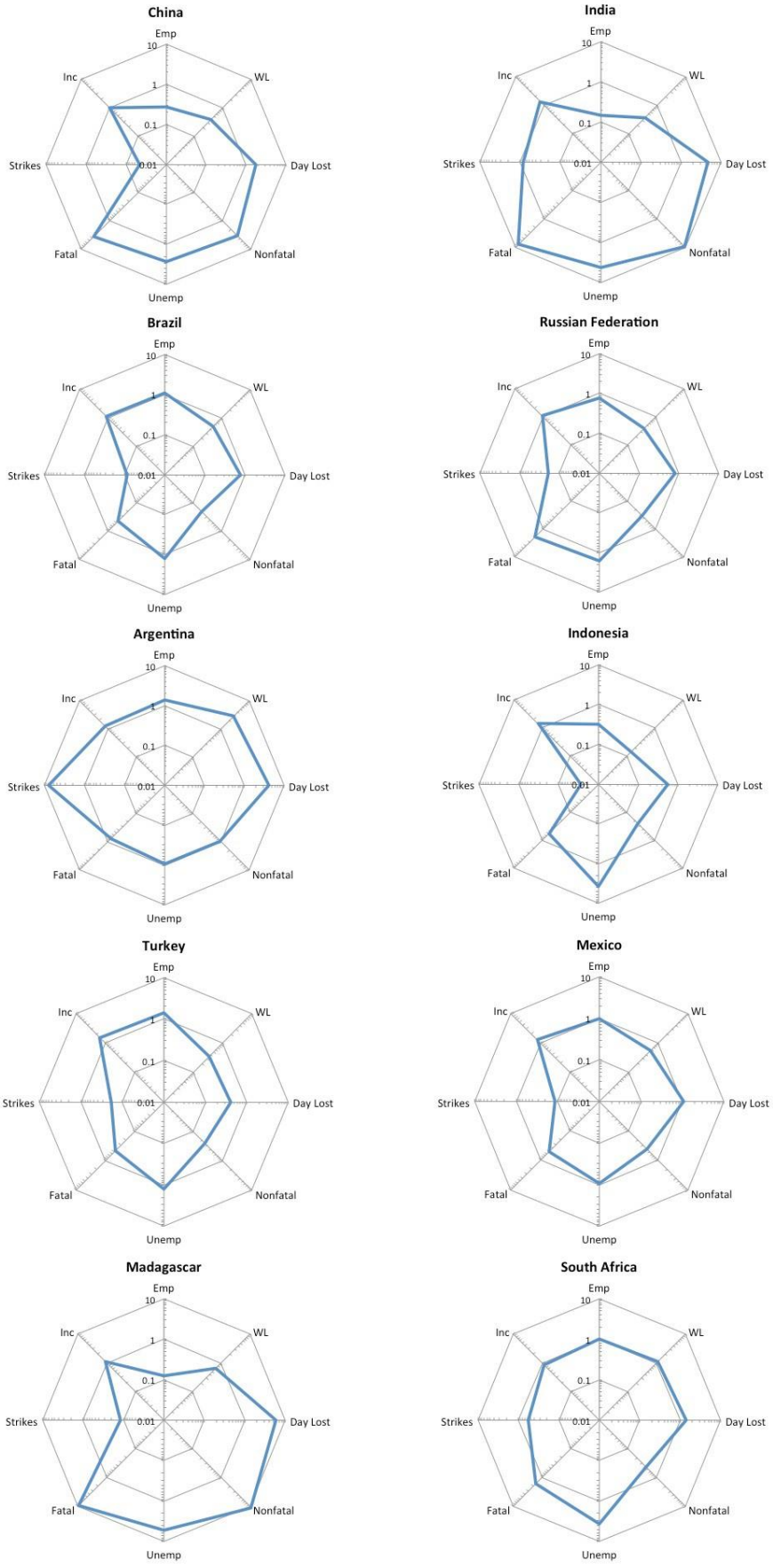

Figure 3a: Social Impact of Work: Total Social Footprint of Work for Developing Nations

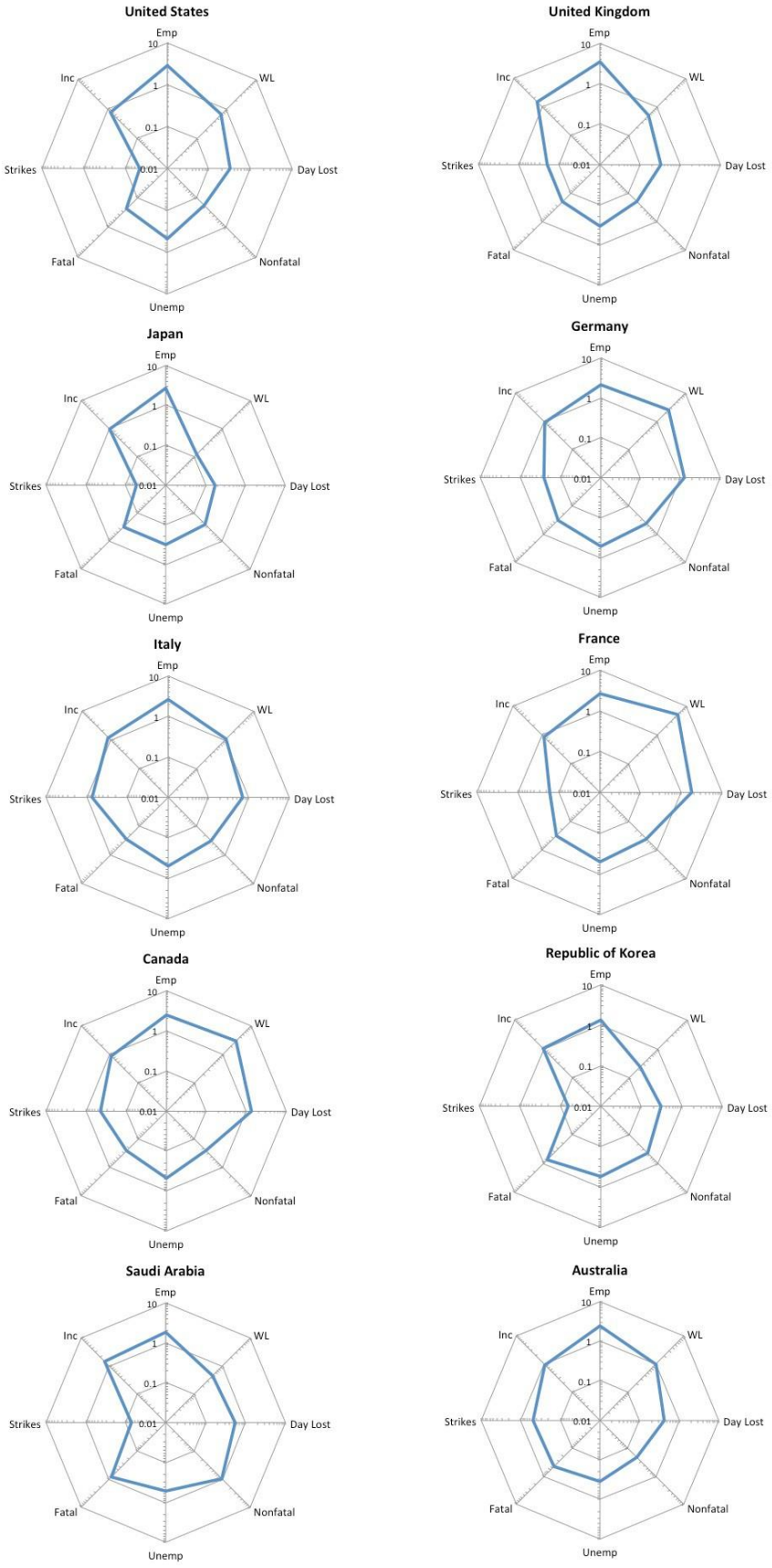

Figure 3b: Social Impact of Work: Total Social Footprint of Work for Developed Nations

The industry sectors contributing to the footprints vary significantly in their impact shapes. For example, agriculture is a significant component of the export market from the developing countries and contributes to the domestic footprint, but contributes more significantly to the imports footprint of developed countries. This was demonstrated using structural path analysis in (Alsamawi A. et al. 2014b, see Table 1; Alsamawi A. et al. 2014c) for trade paths from developed to developing countries. In the developing countries agriculture is generally high in employment, fatalities, non-fatal injuries and unemployment but low in strikes and lockouts and low in income. This is representative of the high amount of non-unionised labour used in the agriculture field in developing countries and the number of small operations. By contrast in developed countries agriculture is often operated at an industrial scale. Mining, in developing countries, can be similarly represented by high employment, fatalities and injuries however in developed countries mining is represented by high strikes and lockouts, high injuries and fatalities, high wages but a low percentage of employment. From a social-LCA perspective, the social impact of the agriculture sector is demonstrated in Figure 1. Although the category of Labour and Decent work was chosen to complement the social footprint developed in this paper, many more details derived through social LCA could be analysed and used to interpret the MRIOA social footprint. By combining the detailed analysis presented by social LCA in Figure 1 with the domestic and imported impact analysis developed as a footprint here, a more thorough picture of social impacts on the ground and due to international trade can be developed.

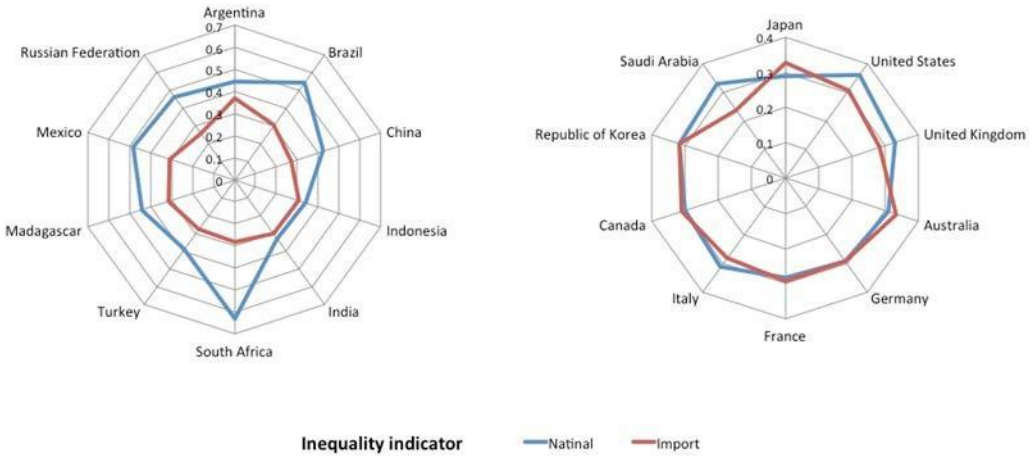

Figure 4: The Inequality of Nations Footprints for Developing (a) and Developed (b) Countries

Legislation also plays a large part in the shape of the domestic footprint and the subsequent total footprint (Figures 2, 3 and 4). European countries such as France, for example, have labour laws which support safe working conditions, decent remuneration and work life balance to be achieved through a 35 hour working week[15]. They also have taxes and transfer payments which promote equality within society (see Figure 4b). The European countries represented in Figure 3b (France, Italy, Germany) all have a similar shaped footprint, as would be expected from operating under similar legislation with respect to working rights (note that the UK has opt out provisions for the Working Time Directive, which may be one reason why it has a slightly

[15] For further information see the European Working Time Directive Directive 2003/88/EC of the European Parliament and of the Council of 4 November 2003 concerning certain aspects of the organisation of working time http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0088:EN:HTML
http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm

dissimilar footprint to other European countries, as well as other differences in legislation and the economy). The social footprints of work for these countries are framed almost around a triangle of high income, high numbers of days lost (representing high standards for sick leave provisions) and high strikes and lockouts (representing a workforce with the right to strike). These high social standards are to an extent passed on through procurement and purchasing conditions. Japan and the US have similarly shaped footprints (see Figure 3b), with more fatalities and unemployment that the European countries. We can see from Figure 4 that the inequality footprint (developed from GINI coefficients, where 0 represents perfect equality and 1 represents perfect inequality) of imports is proportionally larger in developed countries (b) than developing countries (a). The embedded social impacts are roughly divided equally between imports and exports for developed countries (see Figure 4b). However, for developing countries, who consume much less, the social footprint of imports is much smaller than the domestic social footprint. In developing countries there is more inequality domestically than what is embodied in imports. The inequality footprints based on the Gini Coefficients correlate closely with the domestic and imported social footprints calculated for Figure 2.

5 DISCUSSION

5.1 ROLE OF GOVERNMENTS

The inequality inherent within the social footprints of work is integral to economic growth and prosperity and yet can hinder development. Weak labour laws and wage setting mechanisms, controlled by governments through legislation, have led to social inequalities in trade. Through organisations such as the IMF and the ILO there is increasing recognition of and pressure on governments to effectively govern labour regulations and markets to reduce inequality. This is particularly relevant when weak employment regulations lead to low participation in formal employment. When considering a footprint of labour based on trade, we must be mindful of the impact of the black market. The informal or black market economy is not, by its very nature, captured by the System of National Accounts. In some labour markets, over 50% of people work for the informal economy. For example, it is estimated that 68% of Indonesia's workforce work for the informal market[16]. As stated previously, there is an estimated 21 million people worldwide working as slave labour and this labour generates approximately US $150 billion profits in the private economy each year (International Labour Organisation 2014a). This is not captured within our social footprint of work. Some value will be captured at the point in the supply chain where the good or service is sold or purchased in the formal economy, but the labour will not be reflected. Using other methods of analysis within the MRIOA sphere, such as structural path analysis coupled with sector disaggregation using LCA data, can bring some clarity to black market trade through the use of more detailed sector data where informal or black market trade is known to occur (see for example Moran et al. 2014). This method, often referred to as LCA-MRIO analysis, can bring definition to our understanding of social impacts contained within global supply chains and what is happening on-the ground. In action, examples such as work in Argentina show that government regulation can bring about higher participation in the formal labour market, improved social protection and reduce inequality whilst improving business competitiveness (International Labour Organisation 2014b).

The quality of data is an important part of analysis of the informal labour market regardless of the method of analysis used, and developing more robust data on trade and informal markets is

[16] "According to the Central Bureau of Statistics, 68 per cent of Indonesians was employed in informal economy in 2009, often with low pay, hazardous working conditions and no social security". Source: http://www.ilo.org/jakarta/areasofwork/informal-economy/lang--en/index.htm Accessed 19/08/14

an essential part of the process to recognise the scale of labour issues relating to work. Calls for the development of a system of socio-economic accounts (McBain and Alsamawi 2014) go some way towards this, however the collection and collation of accurate data by governments is also essential for addressing inequality, the social impact of work, and the structure of national economies. The social footprint of work, as demonstrated here, will provide an effective tool for comparing progress both temporally within countries and across countries. Social footprint results can be used for communicating within government and to other interested stakeholders of government such as international agencies and NGOs, and businesses importing labour from particular countries.

5.2 ROLE OF BUSINESS AND INSTITUTIONAL INVESTORS

Given the significance of the import component of the social footprint, the role of multinational enterprises in their sourcing policies and the role of institutional investors must also be considered. Legislation such as SEC1520, introduced under the US Dodd-Frank Act 2010 shows that governments do have the power to require business to understand the labour impacts associated with their materials sourcing, and that without tools such as demonstrated here, this information can be difficult to come by (King 2014). In the absence of strong local labour laws, purchasing codes and sourcing policies can give workers an opportunity for fair work conditions beyond national legislation. For example Fairphone, a social enterprise based in the Netherlands, has established secure supply chains to develop and deliver the first smartphones to the market that have high social standards embedded within the product. Working in the electronics industry, an industry sector associated with poor labour standards from metals mining through to manufacturing in developing countries, Fairphone aims to deliver safe conditions, fair wages, worker representation and employee wellbeing in the process of delivering their product (Fairphone 2014). Although securing supply chains to high labour standards to this extent is unusual, many multinational enterprises have specific sourcing policies relating to human rights and working conditions. Unilever, ranked as the world's most sustainable company in a recent GlobeScan survey, has a long history of caring for its workers. This ranges from provision of housing to factory workers and schooling, healthcare and decent wages for plantation workers in the Congo over a century ago, through to current responsible sourcing policies. As part of their Sustainable Living Plan, Unilever aims to reduce their environmental footprint and increase their positive social impact. A social footprint could be a way to demonstrate their positive social impact (Economist 2014). In addition to purchasing decisions, institutional investment also plays a vital role in sending market signals. Fiona Reynolds, managing director at the UN-backed Principles for Responsible Investment, is quoted as saying: "*Labour standards in the supply chains of global food and beverage companies, including retailers, are an area of intense scrutiny for institutional investors. Our signatories understand the importance of this issue on the performance of their investments and the impact it has on the health and wellbeing of workers*."[17]

5.3 ROLE OF CONSUMERS

When discussing social impacts and labour, the role of consumers must also be considered. Individual workers are not separated from the impacts these social footprints of work have shown – they are involved both as individuals that make up the sum and also as the driving forces for consumption. Consumers all, to differing extents, consume domestic and imported labour. The developed world, as shown in this paper and others (for example Alsamawi A. et al. 2014a; Alsamawi A. et al. 2014b; Alsamawi A. et al. 2014c; Gómez-Paredes et al. 2014) consumes more than the developing world. Studies such as Moran et al. (2014) demonstrate

[17] http://www.theguardian.com/global-development/2014/jun/12/ethical-money-investmentfunds

that it is possible to allocate responsibility for social impacts along a supply chain, from production to final consumption. If, as a society, we are to move towards being more sustainable, understanding our impact on the world's society is surely as important as our impact on the world's environment. Just as environmental footprints have become a useful tool for communicating our use of planetary resources to consumers, business and governments, the social footprint has the potential to become a useful tool to communicate our unequal consumption of global labour. The social footprint can be used to highlight where labour is being sourced from, and what the main concerns for each country are in terms of social impacts as well as whether labour is for the domestic or international market.

6. CONCLUSION

It is said that "[t]he journey towards sustainability finds sustainable production and consumption at its very heart" (United Nations Environment Program 2009 p.5). Additionally, it is widely accepted that sustainability encompasses social as well as environmental aspects (United Nations 2012). Hence, recognising environmental and social issues along supply chains, linking producers with final consumers, becomes crucial in any comprehensive sustainability assessment. This capacity, however, is challenged by the complexities of worldwide production and trade, which are predicted to increase. For instance, after the 2008 financial crisis global trade volumes have grown steadily and with the "import demand of high-income economies doubling, [...it] is expected to accelerate"(World Bank 2014 p.16). Furthermore, hosting the view that global trade is the key to economic growth and job creation, in the last G20 summit "leaders delivered a strong statement of commitment to promote free trade" (B20 Coalition. 2014, p2). Accordingly, there are ongoing negotiations for the establishment of a 'Transatlantic Trade and Investment Partnership' (TTIP) and a 'Transpacific Partnership' (TPP), "two mega-PTAs [Preferential Trade Agreements]" (Ibid, p. 16).

As previously mentioned, MRIO models are suitable for the analysis of trade scenarios, and this paper demonstrates that they are particularly useful for examining the social impacts of global trade. MRIOA may be employed in sustainability assessments of specific supply chains; or in a broader context, used to analyse the footprint of nations in a form of quantified sustainability assessment. Such analyses will require, among other considerations, the evaluation of environmental and social footprints (e.g. the CO_2 emissions and social impacts embodied in commodities traded). Then, embodiments in international trade may be traced in order to evaluate final consumers' footprints, as well as to assess global disparities in terms of ecological demands and social demands.

Research into combining several environmental footprint indicators using MRIOA is beginning to occur (see Galli et al. 2012). However, the social dimension of these composite indicator frameworks is still absent. It follows that if comprehensive multi-criteria sustainability assessments are going to be possible, IO-compatible social footprints are an essential and urgent extension. The array of social impacts that social footprints may measure, such as unemployment, occupational health and safety, and income inequality is demonstrated within this paper. This paper provides a methodology and example of a comprehensive social impact footprint for global trade. On its own, this is an advance in the field of social footprinting and contributes to our understanding of both the issues and communication of complex messages. It also highlights the need for further work in considering other major social impacts of our time embedded in global trade, such as gender inequality, discrimination, indigenous rights and living poverty. This research demonstrates the need for accurate country data, which is particularly essential when trying to capture the social impacts of the informal economy. This is particularly relevant for regions where economic activity is expected to increase. This not only

includes current emerging economies (e.g. the BRIC nations), but those regions where greater production is projected. The use of combined LCA-MRIO analysis may provide some solutions.

The social footprint shows the social impacts of work for all countries, and in particular the differences in social impacts between developed and developing countries, and the labour embedded in imports and exports. If, as a society, we want to reduce inequality, we need to understand where it currently resides, what the drivers are, and what the ideal social footprint might look like for a country which promotes just working conditions for its own workers and those abroad working on its behalf. The social footprint of nations goes some way to demonstrating what the current social impact of work is, and how we can measure our progress as a society.

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8. CONCLUSION

When I started my research in 2010 I had a lot of questions, and not many answers. There were not many particularly useful, quantitative ways to assess global supply chains that didn't involve physical social audits. When I started to discuss my initial results with friends and colleagues one of the first questions people asked was 'what can I do about it?' This was a particularly common response to the coltan research (Chapters 4, 5). In response to quantification of social impact (and in particular, loss of human life), people asked me how to make sure they were not contributing to the troubles in the DRC. I had no ready answer despite my research. Some of the only organisations taking action in Australia were the zoos, who were advocating actions ranging from boycotts to mobile phone recycling. Recycling has been successful, with recycling material stock now a significant input to the world market. The US Geological Survey 2014 minerals summary report for tantalum stated that recycled and scrap tantalum represented 51% of tantalum imports into the US (USGC 2014). Boycotts, however, are not always appropriate particularly when they relate to people and livelihoods. In this case, to boycott coltan mined in the DRC is to starve workers of a much needed income. As Chapter 7 demonstrates, work is often difficult and troublesome, but generally vital to generate a living wage, support families, education and a decent way of life. In 2010 there were no clear alternatives that would allow us to buy socially conscious electronics goods. There were coalitions and industry initiatives working to improve the social and environmental impacts of the industry, there were sustainability rating tools rating companies working in the electronics area, and news stories about how unsafe working in the electronics industry was. There was relatively little discussion in mainstream media about inequality within and between countries, as discussed in Chapters 2, 3 and 7.

As I was preparing my paper in March 2013 for the 12th International Conference on Environmental Justice and Global Citizenship (see Chapter 5), a light was beginning to break through at the end of the dark tunnel of global supply chain injustice with respect to conflict minerals (tantalum, gold, tin and tungsten). In 2010 the US Dodd-Frank Wall Street Reform and Consumer Protection Act had set up the provision for reporting on conflict mineral use under section 1520 of the Securities Exchange Commission. A campaign started in 2010 to raise awareness of minerals from the DRC funding conflict, and linking this to electronic goods. This campaign evolved to eventually become Fairphone. Fairphone's aim is to produce a socially and environmentally responsible phone using life cycle design, conflict free minerals and fair wages in factories. In 2013 Fairphone registered as a social enterprise, based in the Netherlands. After presenting my paper to the conference at Oxford University in July 2013, one of the participants, based in the UK approached me. He had placed an order for one of the first Fairphones, production of which was to start later that year. Solutions were beginning to evolve. However, acceptance of using MRIOA for social impact analysis has been slow. It has taken two years and many revisions to have the paper on MRIOA-LCA social impact assessment (Chapter 4) accepted for publication, and even now the editor is still unsure if there is a place in the respective journal for social footprinting. To the extent that the article will only be published with an opportunity to comment from the readership community, and an opinion piece on social footprinting and why it fits within industrial ecology (see Appendix 1). One of the main reasons for opposition to this paper appears to be the quantification of deaths. Insurers have been attaching monetary values to life and death for many years. It is clearly a shocking thought that a value on a life can be associated with consumption. The delay in getting this particular article published has left room for other, less controversial social footprints to begin to be published. Acceptance for socially-extended MRIOA is beginning to emerge.

Fast forward to July 2014 and the scene has changed considerably. The IMF, traditionally in support of growth at any cost, is now selling a message that inequality is bad for economic growth (Laguarde 2014). 'Rock star' economists (Dungey 2014) like Joseph Stiglitz and Thomas Piketty are filling auditoriums around the world and hitting the New York Times' Best Seller

lists with books on inequality such as The Price of Inequality (Stiglitz 2013) and Capital in the 21st Century (Piketty 2014). I attended a talk given by Joseph Stiglitz at the Sydney Town Hall in July 2014 – the message was consistent with many of the findings within this thesis and both Piketty and Stiglitz go some way to suggesting what could be done by governments, companies and to a certain extent individuals to slow the progress of rampant inequality. Chapter 7 provides a prototype for social footprinting which could be used to understand how social impacts such as inequality are changing across countries and across time. The social footprint is a culmination of my thoughts and academic pursuit in writing this thesis. As I write, an article in the news today discusses the need to understand how other countries are bridging the gap between rich and poor, and the impact that inequality has on a nation's growth (Gittins 2014). Social footprinting could be one way that we can better understand inequality.

The electronics sector is also changing. In 2014 well known electronics sector brands Intel, Apple and Hewlett-Packard announced that they have conflict free supply chains. By 2nd June 2014 US companies were meant to report to the US Securities Exchange Commission on the source of origin of potential conflict minerals, and whether their supply chains were conflict free. According to a report by a regulatory compliance auditor, 1277 companies submitted reports on their possible use of conflict minerals (King 2014). Although less than 6% of those met the full SEC requirements, this is many more companies than in 2010 that were investigating their global supply chains for social impacts in the electronics sector. In 2013 the 2nd edition of the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas was released (OECD 2013). In January 2014, the Conflict-Free Sourcing Initiative had validated conflict-free smelters or refiners of all four conflict minerals for the first time and as at July 2014 there are 98 smelters (turning ore into metal) certified as conflict free under this program. The first batch of 25 000 Fairphones was sent out in January 2014, with orders being taken in mid-2014 for the second batch of 35 000 phones (available only in Europe at this stage).

MRIOA in itself will not change social impacts within global supply chains. It will, however, help us quantify and identify the size of impacts. If we believe the saying that things that don't get measured don't get managed, then socially-extended MRIOA has a role to play in the measurement of social impacts in global supply chains. I started this research by piecing together a possible supply chain from many reports and accounts of events, and working out what the social impact indicator was when looking at coltan mined in the DRC. No examples existed at this time of using MRIOA for this kind of social analysis. I'm still not sure that they do. There were no social footprints using MRIOA as a tool to develop them. During the time that this thesis is being reviewed, it is likely that the Global MRIO Virtual Laboratory (Lenzen et al. 2014) will become available as an online tool. The Virtual Laboratory will bring together researchers, research facilities, data sets and computational tools to advance the development and uses of MRIOA. The user interface will also enable non-technical users to download and manipulate input-output data. This is a huge advance in technology from when I started my PhD. I hope this online portal will deliver MRIOA in to the hands of many users from a range of perspectives including business, governments, NGOs and students, in a similar way to how the Social Hotspot Database has enabled all of these groups to access relevant data in a useable and presentable format to better understand their social footprint. In a paper looking at the next 25 years for IOA, Manfred Lenzen envisaged a future for supply chain analysis and linking upstream production impacts with downstream consumption that would fit perfectly with where I envisaged this research could go when I started. His view of the year 2036 has such clarity that I can but quote him here:

> *Modern surface teller chips – transparent non-toxic nanolayers sputtered directly onto products – are recognized in staff-less,*

> *geographically mobile product outlets, linking every transaction in the world to WorldStat's HAL in real-time, tagged with information on the product's value, environmental-resource-societal satellite attributes, MDHS code, GIS code of the point of transaction, as well as seller and buyer ID.(Dietzenbacher et al. 2013; 374).*

The vision is slightly scary, but certainly possible. In the future research should be conducted using high quality data, potentially at an industry level, to enable social impacts to be allocated to companies or consumers with a higher degree of certainty. The combination of high resolution MRIO databases, big data sets and LCA data, and cloud computing should lead to greater collaboration between research institutes and more detailed analysis. MRIOA is already being used for policy analysis (as shown in Chapter 6) and this should continue for both intra- and inter-country analysis.

Many of the crises facing our society (inequality and climate change to name but two) require a global rather than local approach, and MRIOA is ideally suited for this kind of policy analysis of both what happened in the past and what may work in the future. I would like to build upon the work in Chapter 6 and develop an even more robust and understandable method for social footprinting. Working for WWF, I am aware that as an organisation they place a great deal of importance on the biannual WWF Living Planet[1] report, based on the Global Footprint Methodology for creating a country ecological footprint. The complex information contained within an ecological footprint is used by WWF as a science communication tool. The reports communicate environmental pressures (and progress, where appropriate) in a relatively clear manner. I would like to develop a methodology for social footprinting that is complementary to the ecological footprint, although based on MRIOA and LCA. This could be used by a range of policy makers, and perhaps as a tool for social justice NGOs such as Oxfam in their Behind the Brands[2] campaign. For myself, I hope to be part of this research but also to bridge the gap between academia and business to ensure MRIOA is used when analysing and assessing social impacts in global supply chains.

[1] http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/

[2] http://www.oxfam.org/en/grow/campaigns/behind-brands

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APPENDIX: MUSINGS ON SOCIAL IMPACTS

ARE GUNS PAYING FOR YOUR PHONE?

Published online as Are Guns Paying For Your Phone? New Matilda, August 2013

We love smartphones but new research into mineral supply chains points is exposing the grim social and environmental costs of consumer electronics, writes Darian McBain

Apple recently released its third quarter fiscal results showing that whilst overall profits are down the sales of iPhones are up by 20% [http://www.apple.com/pr/library/2013/07/23Apple-Reports-Third-Quarter-Results.html]. Clearly smartphones are selling well. So well, in fact, that Apple, who currently are responsible for 17% of the worldwide smartphone market, are considering releasing a cheaper version of the iPhone, to capture a different segment of the market [http://www.guardian.co.uk/technology/2013/jul/24/cheap-iphone-price-lte-plastic-apps]. What is involved in making a cheaper phone? The technology reports will give you the specification differences – screen sizes, camera pixels and processor speed. We can compare features on a Nokia Lumia with a Samsung Galaxy with relative ease – this isn't just an Apple thing. What of the human cost in making a smartphone? This isn't covered in the specifications, and yet is a very real issue for people involved somehow in the production of a smartphone, laptop computer or games console. People live and work in terrible conditions and even die to make our latest gadget a bit faster and thinner. Is this what we are signing up to when we buy new electronic goods? How can you tell what happens behind the wall of glossy marketing For example, did you know that a small portion of the $400 you just spent on a smartphone could be funding rebel guns in the Democratic Republic of Congo (Congo)? New research at the University of Sydney has shown a way to link the human impacts of production with consumption.

The Congo suffers from its abundance and its vastness. From trade in rubber and ivory in the 1800s to the three Ts of the technological age – tantalum, tin, tungsten – as well as gold, diamonds and timber, the people of the Congo have rarely had their lives enriched by the resources of their country. We all know the story of blood diamonds from Sierra Leone. Less is known about the story of coltan, a surface deposit mined in the Congo. In a long supply chain coltan gets processed into tantalum which is used in lightweight capacitors for electronic goods as well as in alloys, armaments, lenses, cutting tools and medical devices. Lightweight capacitors are one of the reasons that electronic goods such as phones and computers have been able to become so small and portable. When tantalum is mined in countries such as Australia or Canada, labour and conditions are controlled through corporation policy and legislation. However in the Congo mining is usually artisanal – anyone with a shovel can have a go at digging up the earth to find some black gold – and the conditions can be terrible.

Tantalum isn't one of the 17 chemical elements defined as a rare earth elements by the International Union of Pure and Applied Chemistry (IUPAC) but has many similarities when considering its role in the supply chain, such as dispersal of sources, low abundance combined with high demand, bottle neck controls in the markets, and environmental destruction in mining and processing the mineral [for further information see http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/mcs-2013-raree.pdf]. Not all of the world's supply of tantalum comes from the Congo as coltan, nor is all tantalum associated with death and war. The use of coltan to make capacitors for electronic goods becomes a problem when the sale of coltan funds a civil war and the social impact on the local population includes death, mutilation, rape, child soldiers and high mortality from treatable diseases due to the general breakdown of society.

A new study at the University of Sydney has used economic modelling to follow the supply chain of coltan in 2000, tracing it from artisanal mining in the DRC, across porous borders to Rwanda, through intermediate ports for processing and then to final consumers of electronic goods (and cars and medical devices) throughout the world. The novelty of this study is that it uses economic data, based on the System of National Accounts (the data used to develop statistics such as GDP) in the form of Multi-Regional Input Output Analysis (MRIO) to associate deaths in the Congo with final consumption. Estimates of deaths from the African Civil War during this time range from 2.5 million up to 9 million. We know that the sale of coltan in the DRC funded the civil war. We know, for example, that in 2000 coltan was worth more than diamonds or gold. One rebel warlord famously told a US journalist that in 2000 coltan delivered US$1million per month, whereas diamonds only brought in US$200 000. And in 2000, in the middle of the dot com boom with new laptops and game consoles being produced at a rapid rate, that is most likely where the profits of the sale of coltan were channelled. The study uses the Eora MRIO database [www.worldmrio.com] developed at the University of Sydney to associate an estimated 2 million deaths in 2000 in the Congo with hypothetical final consumption in countries including as the USA, Germany and China (results available and papers drafted but not published as yet). This study demonstrates that we could quantify the social or environmental impact of the goods we use, and utilise this information to inform decision making just as much as technical specifications do.

Skip forward to 2013 and the production and supply of electronic goods still have a high human toll. Impacts range from worker deaths in China in factories such as Foxconn due to unsafe use of chemicals or excessively long work hours, to e-waste stockpiles leaking chemical cocktails in the third world. New sources of tantalum are emerging, such as in Colombia and Venezuela, which are again being linked to the funding of rebel groups and war [http://www.semana.com/nacion/articulo/la-guerra-coltan/110119-3]. Several schemes have been set up to improve supply chain transparency and certify conflict free minerals but most have failed due to the complexity of the supply chains, the number of parties involved, and our love of cheap goods. However a social enterprise called Fairphone [www.fairphone.com] is now offering the first conflict free smartphone on the market (sadly EU and US only at this stage), with a tightly controlled supply chain using conflict free resources from the Congo and ensuring good working conditions at their factory. The first production batch of Fairphones was primarily funded through crowd sourcing and in that seems to be the key to equity in the electronics supply chain – consumer action. People need to take more responsibility for what they purchase. Movements such as Walk Free [www.walkfree.org] are calling on consumers to lobby big business to end modern slavery in the supply chain. One of their recent campaigns calls on Nintendo to source conflict free minerals. Ask your retailer some searching questions about the providence of your products, and in turn ask the same of your brand name producers. The more times we ask, the more producers have to take our concerns seriously.

ANALYSIS ENLIGHTENS SUPPLY CHAINS

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"Follow the money" has been a catchphrase since it was first used in the 1976 film *All the President's Men*. Although that reference was about corruption and intrigue, following the money in supply chain analysis is equally interesting.

Money flows through economies from country to country, sector to sector. Most countries capture this flow of money through collecting data in accordance with the UN System of national accounts. National accounts are used to calculate economic statistics, such as Gross Domestic Product and Gross National Product. They are also used to calculate tables (or matrices) that demonstrate the flow of money in a country between industry sectors. These tables are called input-output tables.

In Australia, the data is collected and collated by the Australian Bureau of Statistics. The input-output tables show details such as Australian production, imports, the intermediate uses of production, consumption (including final uses for domestic, export and government markets) as well as taxes and subsidies in terms of AUD. There are 19 divisions which equate to sectors such as mining, construction, health care and social services, and 86 subdivisions which are then broken down into groups and classes, according to the ANZSIC codes. This allows a detailed analysis of the Australian economy by refined sectors.

Using these input-output tables, you can follow a supply chain by calculating how much input from different industries it takes to make $1 output in your industry. Your supply chain can be broken down not into just one path, but a tree structure of paths leading to your product (and beyond), from the coal mined to generate electricity used in production, to the accountancy used to manage your business to final consumption in the household sector (or elsewhere). By using input-output analysis, you can understand all the sectors involved in the value chain for an industry sector. If you know your marketshare within an industry sector, you can also proportion costs appropriately to your business. This enables you to calculate, for example, a full supply chain breakdown of carbon emissions (useful for Scope 3 reporting). Waste satellite accounts can help you understand how much each step of your supply chain generates waste. You can also analyse risk by understanding where the most crucial connections in your supply chain lie.

However, supply chains are frequently extending beyond Australian shores. As the length of supply chains increases, so does the complexity and, in some cases, risk inherent within them. With disasters such as the collapse of the Rana Plaza in Bangladesh earlier this year, resulting in over 1,000 deaths, comes the shock that many companies do not know where their supply chains extend.

As a business, you can outsource production and processes, but not all of your responsibility.

As production is increasingly internationalised, how can procurement professionals better understand global supply chains? One answer is through the use of multi-regional input-output (MRIO) analysis. Through the process described above for individual countries (or regions), multi-regional input-output analysis uses the economic data collected by each country and associates them allowing trade flows to be traced between sectors in different countries. Although the initial concept for MRIO analysis was proposed in 1951, it wasn't until around 2008 this was possible due to the extensive data and computational power required.

Using structural path analysis with specific satellite accounts, MRIO analysis can be used to elucidate many supply chains and the risks contained within them. Economic risks are generally well understood and managed closely by procurement and finance teams. Environmental and social risks, while often listed on the risk register, are rarely accounted for using economic techniques. The use of input-output analysis can bring economic data clarity to supply chain issues including wage inequality, trade in endangered species, carbon footprints, greenhouse gas emission accounting and the human cost of labour.

As computing power increases, so does our ability to use input-output analysis to assess supply chains, consumption and production, and understand environmental footprints. Let us consider two recent studies using MRIO to assess supply chains. The first, published in Nature in 2012, used MRIO to show how international trade, when traced along complex routes, is threatening species. By linking 25,000 threatened Animalia species with 15,000 commodities produced in 187 countries, this study evaluated more than 5billion supply chains to better understand how trade impacts threatened species. The study found that international trade threatens 30% of global species, and that the consumption of items such as sugar, tea, coffee and fish have a much greater impact in developing countries than developed countries. An interactive map for this study demonstrates the power of MRIO. As any supply manager can tell you, evaluating 5 billion global supply chains any other way would be challenging.

The second study we will look at, reported recently in New Matilda, uses MRIO to follow the supply chain of a conflict mineral. Conflict minerals, so-called because the profits of mining fund civil wars and further conflict, are present in many ITC supply chains. Companies listed in the USA will know this because the US Securities and Exchange Commission requires them to report publically on their use of conflict minerals under the Dodd-Frank Act. To report requires understanding your supply chain, and the origin of components.

This study retrospectively traced the supply of coltan from the Democratic Republic of Congo (DRC) from mining to processing and manufacturing and final consumption across the world. Where the coltan ended up was of interest, as most processors and manufacturers denied ever using material sourced from conflict in the DRC. Did these manufacturers not know where their supplies were coming from, or did they deliberately ignore the source? This study also associated the deaths in the DRC due to the mineral funded conflict with end user consumption. Again, MRIO proves to be a powerful way to elucidate a complex global supply chain.

Our ability to analyse production and supply chains using input-output analysis is increasing and it is now up to the procurement and supply community to consider how these tools can be used to help their profession. Extensive computational power is available through MRIO databases such as Eora, a model developed by the University of Sydney (see www.worldmrio.com). A new project to extend current capability to analyse environmental and social impacts using input-output analysis is currently under way, bringing together knowledge from across Australia and the rest of the world. The Industrial Ecology Virtual Laboratory will integrate diverse data streams with input-output analysis to generate the ability to conduct life cycle assessments, carbon and water footprints as well as analyse policy scenarios. Current topics for research include the biofuels industry in Australia, material efficiency, industrial symbiosis and environmental health effects. With the extensive research going on to develop this field, input-output analysis will increasingly become part of the toolkit used by procurement professionals to understand supply chains and manage the risk within them.

IS SOCIAL FOOTPRINTING RELEVANT TO INDUSTRIAL ECOLOGY?

Submitted by request in 2013 to *Journal of Industrial Ecology.* The commentary will be published alongside Chapter 4 in 2014.

"Using footprinting tools to develop country, industry or product specific information would be an innovation of the information age and a logical expansion of industrial ecology."

Industrial ecology covers a broad range of themes around production, from systematic analysis to environmental innovation and efficiency. A cornerstone of production is human input but relatively little is understood about the social footprint of productivity in industry. In traditional economic resource productivity models, direct costs such as labour and material inputs are accounted for with an aim to ultimately increase the value of the product. Industrial ecology brings a further environmental dimension to this equation by considering how environmental performance can both increase value and decrease direct costs. But what is industry without society, and how do we take into account the social dimension? Business relies on people both to produce and consume. By considering social dimensions such as labour and inequality, a social footprint can provide a more robust view of resource productivity, sustainability and pathways to innovation.

Industrial ecology has used ecological and carbon footprinting as tools to communicate environmental impact, inform policy, and generate comparative measures of performance and progress. Admittedly, debate rages over the application of ecological footprint comparisons and usefulness of concepts such as bio capacity and global hectares, as illustrated recently in the Journal of Industrial Ecology (JIE) by Wackernagel in response to an article by van den Bergh and Grazi. As pointed out in their article, footprinting is a concept that is well used by popular media, pressure groups and business, if not well understood or applied. A footprint is a useful method for accounting for environmental indicators (such as greenhouse gas emissions, in the instance of a carbon footprint) for an entity, be it a region, country, industry or even a person. From this we can take that there is an essence of the footprint model that can be captured to help people understand impact assessment and sustainability accounting. To date most of the focus on footprinting has been on environmental impact and assessments – let us call them environmental footprints in this instance (including both carbon and ecological footprints). To take a triple bottom line approach, more focus is required on accounting for the social impact of production and business.

There are increasing demands on businesses to be proactive around their social footprint, how they manage social impacts and add value to society. Social footprints can measure social impacts in a similar way to that used by environmental footprinting to measure environmental impacts. A range of social and wellbeing indices exist, measuring comparative impact and progress from a country level to a personal level. Examples at the country level include the United Nations Development Program's Human Development Index, the Genuine Progress Indicator and the OECD's Better Life Index while at the personal level numerous subjective wellbeing indices and happiness indicators are available. Similarly to environmental footprints, social/wellbeing indicators range from composite or aggregated indices (eg Human Development Index) to suites of indicators (Better Life Index). They are usually based on a range of quantitative and qualitative variables, taking into account a range of personal and societal factors, including work, income, housing, education, health, community connectedness and personal happiness. A key difference between these indicators and a social footprint, in the context of industrial ecology, is the relationship to industry. A social footprint, as opposed to a social/wellbeing indicator, accounts for social impacts in relation to work or industry.

Social footprinting can illuminate issues in industrial ecology that can be used for competitive advantage in corporate strategy and to develop public policy by better understanding risk, resource availability, impacts and outcomes. Many of the social issues that can be measured and addressed in social footprinting are not so much well-being measures as conditions of work: wage disparity, wage inequality, work conditions, child labour and forced labour as defined by the International Labour Organisation (ILO) Conventions. Both business and government have a keen interest in better understanding social impact in relation to work and the economy and as this area of study evolves industrial ecology has a role to play in suggesting and defining methodology, terms and uses. Emergent examples of social footprinting are being published in the JIE, demonstrating outputs and potential uses. One recent example by Alsamawi et al examines the master servant relationship of income inequality in trade between countries. Examples published to date have been non-constrained, having more in common with a carbon footprint than an ecological footprint. However, future social footprints could include constrained social parameters, such as a lifespan or legal age limit bringing more similarities with an ecological footprint method.

Just as design for the environment has been a cornerstone of companies from 3M to FujiXerox, design for society could become equally important in the future. Companies that have high profiles for their negative social impacts in the supply chain, such as Apple and Nike, need ways to quantify their social impact. Social footprinting could be one such tool. Social footprinting may in the future become not only a measurement and investigation tool, but also a useful way to quantify and communicate an aspect of sustainability that has, to date, been largely qualitative.

A search on the internet shows that social footprinting is still in its infancy but developing in uses and applications. It is in these applications that a very clear example of a link with the past and future of industrial ecology can be found. Since 1997 the JIE has published over 15 pieces about environmental processes in the paper and pulp industry. This includes an innovative special issue in 1997 with three papers addressing 'the environmental and economic aspects of pulp and paper….and the role of industry in achieving environmental goals' (Lifset 1997) and stretches into 2013 with a feature on extended producer responsibility for packaging and print material in the USA (Gardner 2013). Common keywords in these published papers include energy, water, waste, emissions, technology, purchasing, materials and recycling. The manufacture, use and reuse of paper are clearly an issue for industrial ecology.

On the same topic, WWF produce guidance on their website titled 'The Ecological and Social Footprint of Paper' as part of their tools and guidance for business. The WWF guidance covers not just environmental impacts such as chemical treatment, CO2, waste, water and air emissions, as you would expect from the search of the JIE, but also covers issues such destruction of habitat and livelihood, working conditions, corruption, human rights and health. A quick look at the WWF guidance reveals that most of the assessment done on the social aspect of the footprint is qualitative (primarily case studies). Why is there such a difference in the discussion on the impacts of society's consumption of paper between the two sources of information? It is clear that leadership on this issue is required, and that methodologies for accounting for industrial impacts are needed that take social impacts into account.

The social impacts of industry are increasingly being felt not just directly in the workplace but also in supply chains. Supply chains are another area of industrial ecology, frequently analysed for efficiency and environmental impact. However industrial disasters such as the collapse of the Rana Plaza in Bangladesh in April 2013, killing 1129 people working for the global textile industry, are all too frequent. From deaths due to conflict when mining in Africa for rare minerals to workers dying in electronics manufacturing factories from exposure to chemicals in

China, social impacts are as much as part of the industrial ecosystem as environmental impacts. How can we understand the inequality inherent in industries throughout the world? Social impact can and should be part of industrial design. Social impacts should not be ignored just because we currently do not have standard methods to measure them. By developing a social footprint as part of an industrial ecology process, we could better understand how to design for society and have improved social (and environmental) performance of products.

If we make this link between a social footprint and work, we assume that there are methodologies that can be borrowed and adapted from environmental accounting within industrial ecology. From the background of industrial ecology, two of the most readily applicable methodologies are input-output analysis (using either social accounting matrices or extended social accounts) and social life cycle assessment. These methods represent both a top-down and bottom-up approach, and are firmly linked to production and industrial ecology. Other methods for social footprinting have been suggested, such as the context based Social Footprint Method advocated by McElroy, based on sustainability quotients and limits. The Social Hotspot Database, based on GTAP Global Input-Output modelling and using Life Cycle Assessment software can be used for developing detailed assessments of worker social impacts in supply chains. More methods will evolve as understanding of our data requirements increases, and particularly as corporate reporting requirements encourage a focus beyond annual financial reports. For example the Global Reporting Initiative G4 guidelines contain a much stronger focus on understanding supply chains and social impacts than previous guidelines. Governmental compliance reporting is also pushing for further information on social impacts in the supply chain, as exemplified by Section 1502 of the US Dodd-Frank Act requirements for reporting on use of conflict minerals.

Industrial ecology needs to evolve to consider all impacts of industry, not just the economic and environmental impacts. Business, government and consumers need information on functionality as well as sustainable use of natural resources and protection of human rights. Extended producer responsibility needs to extend beyond environmental impacts to the direct social impacts of business. With the proliferation in LCA databases and multi-regional input output databases in the past decade due to increased computing power and the ability to store and share data, using footprinting tools to develop country, industry or product specific information would be an innovation of the information age and a logical expansion of industrial ecology. The environmental and social footprint of a product, presented in a comparable and understandable report could help consumers to be more content with their choices and enable business to better understand how to design for the environment and society and manage their risks. By developing techniques for social footprinting, and combining this data with environmental footprinting a whole new world of information will be available to encourage understanding of impacts, performance management, system design and innovation.

Further Reading

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SUPPLY CHAINS FROM HELL – ALLOCATING CORPORATE AND CONSUMER RESPONSIBILITY FOR THE SOCIAL IMPACTS OF PRODUCTION

Submitted to *The Conversation* in 2014 and initially accepted but then rejected on the basis that as I work for WWF this is not academic thought but activism. These thoughts are still searching for an activist home.

A recent news report caused me to recall an incident from long ago in my childhood. The family had sat down at the dinner table for a Friday night meal involving prawns, lovingly prepared by my mother. When my father sat down he queried where the prawns were from. To which she answered from the seafood merchant in our local town, where she always bought the seafood. "I'm not eating them!" my father declared. "These prawns," he proclaimed, "are from Thailand, where they are farmed in cages and fed on pig effluent[1]!" We all sat there, staring at the prawns on their beds of iceberg lettuce with a blanket of thousand island dressing, and wondered how my father had divined the providence and diet of our dinner. To this day I still don't know how he came to this conclusion, but I recall that the cat ate well that night.

With age has not come great wisdom. I still can't look at a prawn and tell where it is from. But I suspect that I'm not alone. A recent expose by The Guardian has shown, after a six month investigation, that there are allegedly horrific labour practices hidden within the global prawn supply chain. Allegedly, the Thai fishing industry has been using slave labour, forcing people to work for no money in terrible conditions and under the constant threat of violence. The story tells of migrant workers from countries such as Burma and Cambodia who have paid brokers to find them factory work. Instead they are sold to captains of fishing boats operating off Thailand, and forced to live as slaves without papers and without hope of escape. The report tells of the long and complex supply chain, starting at the production end with "trash fish" caught in international waters by the fishing boats, progressing on to turning the "trash fish" into fishmeal, which is then fed to the farmed prawns, and then travelling along the supply chain to where prawns are exported to markets around the world and sold to consumers. Although the initial report focused on European and US retail outlets, the prawns also end up in Australian markets.

Most of the retailers interviewed for the story stated that they do not condone slavery within their supply chains and are actively engaged in one way or another to eliminate slavery within this supply chain. Slavery is illegal in all countries that are parties to the treaties of the Universal Declaration of Human Rights (specifically Article 4) and the current action threatens to put Thailand at risk with international trade partners through being downgraded on the US Department of State's Trafficking in Persons Report. So if the retailers are against slavery, and most of our governments are against slavery, and consumers are against slavery, how has modern slavery become such a massive issue?

When we read or hear stories like this, about supply chains that originate in a living hell for some people, we tend to feel guilty and a little bit responsible. Certainly I do. But how responsible are we? What if we could tell how much of the social impact you are responsible for? Until now that hasn't been possible. Supply chains are complex and global. However, a new study from the University of Sydney (Moran et al. 2014) shows the possibility of allocating social impacts along a global supply chain from production to final end consumers. The study looks at the mining of coltan in the Democratic Republic of Congo (DRC) in 2000. Coltan, otherwise known as tantalum, is mined in many places around the world, including Australia. However in 2000 there was a dot com boom and coltan from the DRC became worth more than

[1] Not the actual word used

diamonds. It earned the name black gold, because its value for electronics components such as lightweight capacitors became so high that a valuable black market sprang up around its sale from the DRC. The study uses multi-regional input-output analysis (MRIOA) to associate deaths in the DRC due to the coltan-funded civil war with the production and consumption of coltan. The Conversation reported on trade inequality modelled using MRIOA earlier in 2014. Through quantitative modelling , the coltan and associated deaths can be traced through hundreds of supply chains, and allocated to final consumption sectors around the globe. Using the coltan data for this modelling tests the theory of whether social impacts upstream in a supply chain can be proportionally allocated to final consumers downstream in the supply chain. This study stops at the industry and country level. However, by knowing the market share and sales figures and with greater data certainty, social impacts could be allocated to individual companies and potentially even to consumers.

We need more information as consumers to make informed decisions and for corporations to manage risk and impact. At the moment the best consumer stance is either to boycott a product in the hope that it might stop atrocities in the supply chain (when in fact it can perversely take away the livelihood of people who need the income the most) or lobby retailers and manufacturers to change their ways. The world was horrified when the Rana Plaza in Bangladesh collapsed in 2013, killing over 1000 people and injuring over 2500 people. Despite numerous retailers being identified as having contracts with clothing manufacturers within the building, there has been very little done to provide compensation to victims. Would the outcome be any different if you knew that your high street retailer was responsible for a certain number of deaths to bring you this season's latest fashion? It might give us new impetus for barcode activism.

THE ROLE OF BUSINESS IN A SUSTAINABLE FUTURE

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The issue

Businesses provide us with what we eat, what we wear, the homes we live in, the services we utilise and tools for education. Along with the government and the community, business (both for profit and not for profit) and industry provide us with what we need to live and what we want to prosper. The American Economist Milton Freidman stated that "There is one and only one social responsibility of business - to use its resources and engage in activities designed to increase its profit so long as it stays with the rules of the game, which is to say, engages in open and free competition, without deception or fraud." However, increasingly the role of business and industry in helping to create a sustainable future is being emphasised. The Global Financial Crisis of 2008-09 showed us how interconnected we are, where financial crises travelled from continent to continent like shockwaves, as a result of business and government decisions. Similarly environmental and social crises are not contained to one city or even country but are closely tied to business decisions.

Context

Businesses are increasingly recognising their role in sustainability. Many organisations' strategic planning now includes how they are contributing to economic, environmental and social progress as well as the financial bottom line. It is common for companies to appoint a person or team of people dedicated to sustainability performance, link sustainability to position descriptions, have organisational sustainability key performance indicators and even give sustainability oversight to high-level decision makers such as Vice Presidents or Board members.

Whilst pollution of the air, water and soil first brought our attention to corporate impact on the environment drivers for change now include:

- efficiency and the rising cost of utilities such as energy, water and waste;
- environmental legislation and government incentive programs;
- employee and community expectations;
- supplier expectations;
- consumer sentiment; and
- socially responsible investment.

Even school children are having an impact on how businesses are run. Their familiarity with the concepts of sustainability and direct action through purchasing and recycling are having a knock on effect on their parents, who then take these ideas and principles to work. But how do we identify a sustainable business? Investors have for some time been applying evaluation models and methods in order to identify sustainable companies and global methodologies for accountability exist. However as yet there is not one fixed evaluation model and method.

The role of business in sustainability is further emphasised when considering their financial power. Individual businesses have a turnover greater than the Gross Domestic Product (GDP) of some countries. In many developed countries, the market capitalisation of listed companies

is greater than their GDP. According to the World Bank, in 2010 this was true in at least 18 countries, including Australia, Canada, Chile, Malaysia, Singapore, South Africa, the UK and the USA. If this is the case, does business not have a greater responsibility to its stakeholders than returning a profit? Its stakeholders will include shareholders, employees, consumers, government and non-government organisations (NGOs) and the wider community. Stakeholders expect businesses to work towards sustainability because corporate activities have a powerful impact on our social, environmental and economic future. Companies provide goods and services that we want and need, but also have a role in creating a sustainable future.

Historical

Business responsibility beyond profits can be traced back over centuries. Socially Responsible Investment (SRI) probably dates back to the Quakers and Christian groups in the eighteenth century. It was developed to address environmental and social issues resulting from business practices. Corporate Social Responsibility (CSR), the business equivalent of philanthropy, has also been around since commercial trade grew from individuals trading to organised 'businesses'. A good example of early CSR can be found by considering Cadbury, the well-known chocolate and food producer.

Case study: Early Corporate Social Responsibility

'No man ought to be condemned to a place where a rose cannot grow' (George Cadbury).

John Cadbury opened a grocer's shop in Birmingham, England is 1824. As well as groceries, he sold coffee, tea, cocoa and drinking chocolate, believing in providing hot drinks as an alternative to consuming alcohol. John Cadbury was a Quaker, and as such was committed to social justice and preventing human misery and deprivation. Other philanthropic activities he was involved in included leading the campaign to stop young boys being used to sweep chimneys and establishing an animal protection society (a forerunner to the RSPCA). In the 1840s a Royal Commission showed the poor quality of life for those living in the Birmingham slums, where most of his factory workers lived. In 1878 John's sons George and Richard moved the factory to Bournville, four miles from the centre of Birmingham. George believed that factory workers had the right to country air and activities, with clean water and away from the pollution of the cities.

The Cadburys built cottages for workers, and eventually schools, churches, recreation areas and created a thriving community. They created a charitable trust to preserve the community and green spaces that they created, welcoming others into the community and protecting it from overdevelopment. Their hard work paid off and in 1915 a study showed that the general death rate and infant mortality was lower in Bournville than in Birmingham. Cadbury continues with its CSR through the Cadbury Foundation, its environmental commitments and its sourcing policies.

Political

Governments have a role to play in encouraging businesses towards sustainability. Through policy, regulation, education, international agreements and institutional frameworks governments enable businesses for the transition to a sustainable future. Some examples from governments around the world are outlined here.

The European Union Emissions Trading Scheme, EU ETS, is the largest multi-national emissions trading scheme in the world. It was launched in 2005 and is a major pillar of EU climate policy. Under the EU ETS, large emitters of carbon dioxide within the EU must monitor and annually report their CO2 emissions. Based on their emissions allowance, they can either buy or sell their CO2 emissions (emissions trading) depending on their actual annual carbon emissions for the year. The EU ETS engages companies to take energy efficiency measures to reduce their

emissions through economic measures, forcing high emitters to pay for their emissions trading and those who have reduced their emissions to save.

Government policy can also influence businesses by encouraging sustainable consumption and production. The Japanese government set up The Top Runner Program in 1999 as a countermeasure to reduce energy consumption in the civil and transportation sectors. This program provides the standard of energy efficiency for products and is applied to 23 products of machinery, equipment and vehicles prescribed under the Energy Conservation Law. In 2002 the UK government published a 10 year Sustainable Production and Consumption Framework and in Germany in 2005 the Centre on Sustainable Production and Consumption was established.

Government policy has also influenced business sustainability through investment policy. The SRI Pensions Disclosure regulation in the UK came into force on July 3rd 2000, which forced the investment market for pensions to become more transparent. According to the SRI Pensions Disclosure Regulation, schemes must disclose their SRI policy in their Statement of Investment Principles. Since 2000, there have been numerous developments and initiatives that have further fuelled the growth in the institutional SRI market. The concept of materiality in financial accounting standards and regulations has also had an impact on company investment transparency.

Global

There are many business associations and NGOs that promote and support the work of businesses towards sustainability. For example, the World Business Council for Sustainable Development (WBCSD) says that leading global companies of the future will be those that provide goods and services and reach new customers in ways that address the world's major challenges – including poverty, climate change, resource depletion, globalization and demographic shifts.

The UN Global Compact is a strategic policy initiative for businesses that are committed to aligning their operations and strategies within the areas of human rights, labour, environment and anti-corruption. It is a practical framework for the development, implementation, and disclosure of sustainability policies and practices, offering participants a wide spectrum of work streams, management tools and resources to help advance sustainable business models and markets.

OECD Guidelines on Multinational Enterprises is a recommendation for responsible business conduct covering social issues, environment and governance. For example on social issues the Guidelines promote respect the internationally recognised human rights standards and the principles of the International Labour Organisation (ILO). They encourage local capacity building through close co-operation with the local community and encourage human capital formation, in particular by creating employment opportunities and facilitating training opportunities for employees. The Guidelines were updated in 2011 for the fourth time since they were first adopted in 1976.

The United Nations-backed Principles for Responsible Investment Initiative, PRI, was launched in 2006. It is a network of international investors working together to put its six Principles into practice. The Principles were devised by the investment community. They reflect the view that sustainability issues can affect the performance of investment portfolios and therefore must be given appropriate consideration by investors if they are to fulfil their fiduciary duty. The Principles provide a voluntary framework by which all investors can incorporate sustainability issues into their decision-making and ownership practices and so better align their objectives with those of society at large.

Reporting and Disclosure

Reporting of non-financial data is not mandatory in most countries, however many businesses are finding it an increasingly useful tool to communicate their vision and commitments to stakeholders. There are NGOs who assist companies to disclose and report their data voluntarily such as The Global Reporting Initiative (GRI) and Carbon Disclosure Project (CDP) and the International Organization for Standardization (ISO).

The GRI is a network-based organization based in the Netherlands. The GRI's main output is a reporting framework able to be applied to organisations worldwide regardless of size, industry or sector. The GRI has worked to develop industry sector appropriate supplements, and promote good reporting practice. The GRI's core goals include the mainstreaming of disclosure on environmental, social and governance performance. Sustainability reports based on the GRI Framework can be used to demonstrate organizational commitment to sustainable development, to compare organizational performance over time, to benchmark with other businesses and to measure organizational performance with respect to laws, norms, standards and voluntary initiatives.

The CDP seeks to accelerate solutions to climate change by putting relevant information at the centre of business and investment decisions. The process aims to increase transparency around climate-related investment risk and commercial opportunity in the global market place, and drive investments towards a low carbon economy. Over 3,000 organizations in some 60 countries around the world now measure and disclose their greenhouse gas emissions, water management and climate change strategies through CDP, in order that they can set reduction targets and make performance improvements. These data are made available for use by a wide audience including: institutional investors, corporations, policymakers and their advisors, public sector organizations, government bodies, academics and the public.

ISO is a non-governmental organization that forms a bridge between the public and private sectors. ISO is a network of the national standards institutes of 162 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. ISO published the standard ISO 26000 in November 2010 in which it emphasizes the value of public reporting on social responsibility performance to internal and external stakeholders, such as employees, local communities, investors and regulators. This represents an important new level of international attention to the issue of reporting that disclosure on economic, environmental, social and governance performance becomes as commonplace and comparable as financial reporting. Other standards, such as ISO 14001 for Environmental Management Systems have had a significant impact globally on business sustainability. When in the 1990s a large producer of cars required all first tier suppliers to have an environmental management system in place certified to the ISO 14001 standard, there was an almost doubling of the number of management systems in place globally and the auditors required to verify them.

Discussion

One difficulty in assessing the sustainability performance of a business is how to compare across different activities, priorities and performance levels. Business A might focus on reducing carbon emissions whilst Business B might focus on labour standards and community support. Which business is more sustainable? What if Business C has reduced its energy consumption and waste generation but its most senior management salary is more than 100 times that of their lowest paid worker? Is Business C still performing sustainably if inequitably? Should a consumer buy from Business A or Business B? If they are part of a supply chain, how can a business upstream (ie buying their input from other suppliers to make their output products or services) understand the sustainability impacts that are inherent in their purchases? How does an investor understand the risk associated with businesses in relation to sustainability performance?

Investors have led the way in developing evaluation models and methods that take a sustainability point of view, and similar models have been rolled out by major retailers. The models and methods require financial and non-financial data like environmental, governance and social (ESG) performance information which are used for the evaluation. Environmental evaluation criteria can include policy around key environmental issues like greenhouse gases, water and bio diversity. Social evaluation criteria can include the company's social contribution to job creation, workers' rights to association and human rights; and lastly Governance can mean the board's practice, the percentage of independent directors and the independence of the audit committee. These are only some of the evaluation criteria. Some methodologies and their applications are discussed below.

Case study of sustainability evaluation in business

Two of the indexes that are used to assess business sustainability, particularly with respect to investment, are the SAM (Sustainable Assets Management) Dow Jones Sustainable Index (DJSI); and FTSE 4 Good Index.

These two indexes are among the most popular indexes with which to evaluate corporate sustainability. However, there are big differences in their evaluation methodology. SAM DJSI takes a 'best-in-class' approach whilst FTSE4Good relies on negative screening. The explanation is given below.

SAM Dow Jones Sustainability Index

The Dow Jones Sustainability Indexes are based on SAM's internationally recognized leading Corporate Sustainability Assessment (CSA) methodology. The Dow Jones Sustainability Indexes launched in 1999 were the first global indexes tracking the financial performance of the leading sustainability-driven companies worldwide. The results of the annual SAM Corporate Sustainability Assessment form the research backbone for the construction of the Dow Jones Sustainability Indexes. This family of indexes takes a 'best-in-class' approach to selecting sustainability leaders from all industry sectors on the basis of defined sustainability criteria embedded in the SAM Corporate Sustainability Assessment. This means that they include only companies that fulfill certain sustainability criteria better than the majority of their peers.

SAM also provides the opportunity to conduct a dialogue with companies from all sectors and thereby influence incremental improvements in companies' sustainability practices. To be included or remain in the index, companies have to continually intensify their sustainability initiatives. SAM believes this approach will benefit all stakeholders: investors, employees, customers and, ultimately, society and the environment.

FTSE 4 Good Index

FTSE is an independent company jointly owned by The Financial Times and the London Stock Exchange. FTSE4GOOD criteria have been set at a level that represents good practice standards, thus screening out businesses that do not meet the criteria. In addition, the negative screening also excludes specific sectors for their sustainability impacts, such as alcohol producers, arms makers and sellers, companies with breaches in the human rights of employees or local residents, gambling, nuclear power, polluters, supporters of oppressive regimes, pornography and tobacco.

FTSE develops a dialogue with business, providing directions on how to meet the standard. This proactive engagement process has contributed to sustainable changes in corporate practices. Independent committees of senior fund managers, derivatives experts, actuaries and other experienced practitioners review and approve all changes to the indexes to ensure that they are made objectively and without bias.

Sustainability in the Supply Chain

Gathering information and enforcing standards through the supply chain by retailers is also having an impact on business sustainability. Many UK supermarkets, including Tesco, Waitrose and Marks & Spencer require their suppliers to meet extensive sustainability performance guidelines. In the USA, Walmart has introduced a Sustainability Index that aims to impact suppliers around the globe and provide the sustainability information to consumers at point of sale (i.e. in the shop) so that they can make an informed decision about the impacts that are associated with what they are buying. These programs have much further reach than government legislation and are often more binding as it directly relates to what is being bought and sold. For example, the standards set by Tesco for food and beverages sold in the UK have an impact on how growers and producers hire labour in countries as far away as Australia and South Africa. When compared to the time taken for international agreements, such as to the Kyoto Protocol, to take effect and for member countries to commit to and implement these protocols, businesses enforcing high sustainability standards on other businesses can deliver fast, specific and measurable results.

Conclusion

Business and industry have a role in creating a sustainable future. As significant users of resources, employers, neighbours, polluters, innovators and members of every community, the way a business operates is intricately connected to people and the planet. As consumers we all have an influence on how businesses operate through what we buy. If we give preference to consuming less, equity and purchasing goods and services with positive ESG outcomes we can support businesses in their drive for sustainability. We all know people employed by businesses and people who own businesses and many students will one day work in a business. People and businesses are interconnected.

Our methods for evaluating business performance are becoming more sophisticated as we start to consider sustainability issues. Indexes provide companies with crucial insights into their sustainability performance, making them aware of key sustainability issues to be considered in their corporate agenda. Standardized data on sustainability issues is needed to enable investors and consumers to compare the activities of companies. There are initiatives to standardise data which will make it easier for stakeholders to evaluate companies on sustainability alongside financial performance in near future.

Driving sustainability in business is crucial for sustainability in society and can be for the mutual benefit of companies, investors and individuals. As this benefit circle strengthens, it will have a positive effect on societies and economies.

Thinking it through: where do I stand?

Who are some of the big businesses I support through what I buy? Do I know what they do on sustainability?

Are there any indexes that give me more information on what I buy? Have a look at the electronics industry and see how different companies are rated on sustainability. Greenpeace International publish an annual guide on greening the electronics industry. Have a look who makes your computers, mobile phones and games consoles and see how they rate for sustainability performance. Would you choose to buy from another brand based on sustainability performance?

Choose one of your utility providers and see if they publish a sustainability report. Does their report make reference to the GRI? Do they publish any information on their sustainability performance in their Annual Report?

Where do your parents work? Ask if they know what their employer is doing to make their organization more sustainable.

What is happening in your country on emissions trading or carbon taxes? Do you think it will encourage business to be more sustainable?

Action: what can I do?

Your school will buy lots of things, including desks, paper, food and buildings. Think about how your school takes into account sustainability when it buys something. Contact some of the suppliers to your school and ask if they participate in the CDP or write a sustainability report. Ask them to come and talk to your class about sustainability and what it means to them.

Try to research different options next time you want to buy something and see if you can support a business that is trying to be sustainable.

Further reading

Fry Sullivan & Craig Mackenzie. (2006). Responsible Investment. Greenleaf Publishing Limited.

Dana Krechowicz, Shally Venugopal, Amanda Sauer (2010) Weeding Risk. World Resources Institute

David Mackay (1998) Sustainable Energy - Without Hot Air (available as a free download from www.withouthotair.com)

William McDonough & Michael Braungart (2002) Cradle to Cradle: Remaking the Way We Make Things. North Point Press.

Naomi Klein (2000) No Logo. Knopf Canada.

Viewing

The Story of Stuff by Annie Leonard

This 20 minute animated feature shows the environmental, social and economic cost of the things we buy and how they are made. Shorter features, such as the Story of Bottled Water, are also very informative. There are also educational resources and further readings available on the website.

http://www.storyofstuff.com/

Our Story by Cadbury

An interactive website takes you through Cadbury's history, including a story line on their philanthropy. You can also look at their current commitments to sustainability.

http://www.cadbury.co.uk/cadburyandchocolate/ourstory/Pages/ourstoryFlash.aspx

Resources

Carbon Disclosure Project https://www.cdproject.net/en-US/Pages/HomePage.aspx

Climate Disclosure Standards Board (CDSB) http://www.cdsb-global.org/

Energy Conservation Centre Japan http://www.asiaeec-col.eccj.or.jp/index.html

European Commission Climate Action: Emissions Trading Scheme
http://ec.europa.eu/clima/policies/ets/index_en.htm

Eurosif SRI resources http://www.eurosif.org/sri-resources/sri-country-resources/united-kingdom

FTSE 4 Good Index. http://www.ftse.com/Indices/FTSE4Good_Index_Series/index.jsp

International Integrated Reporting Committee (IIRC) http://www.theiirc.org/

International Organization for Standardization (ISO) http://www.iso.org/iso/home.html

OECD Guidelines for Multinational Enterprises
http://www.oecd.org/department/0,3355,en_2649_34889_1_1_1_1_1,00.html

Sustainable Assets Management (SAM) http://www.sam-group.com/htmle/about/portrait.cfm

SAM Dow Jones Sustainable Index http://www.sustainability-index.com/

The Global Reporting Initiative http://www.globalreporting.org/Home

United Nation finance Initiative http://www.unepfi.org/

United Nations Global Compact http://www.unglobalcompact.org/

United Nations Principles for Responsible Investment Initiative http://www.unpri.org/about/

World Business Council for Sustainable Development (WBCSD)
http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?MenuID=1

World Bank Market Capitalisation of Listed Companies

http://data.worldbank.org/indicator/CM.MKT.LCAP.GD.ZS

Walmart Sustainability Index

http://walmartstores.com/Sustainability/

Marks & Spencer Sustainability

http://plana.marksandspencer.com/

Greenpeace International Guide to Greener Electronics

http://www.greenpeace.org/international/en/campaigns/toxics/electronics/how-the-companies-line-up/