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Macro Sustainability across Countries: Key Sector Environmentally Extended Input-Output Analysis

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Abstract: When formulating economic development strategies, the environment and society must be considered to preserve well-being. This paper proposes a comparative sustainability assessment method using environmentally extended input-output analysis and multi-criteria decision aid. Using symmetric input-output tables and sectoral CO₂ emissions and employment data for six countries, linkage coefficients are calculated for 163 sectors in each country. Multi-criteria decision aid tool, ELECTRE III, is used to derive outranking relationships among each country's sectors using these coefficients as criteria, resulting in a hierarchy of sectors ordered by sustainability. Sectors that frequently appear at the top of the six hierarchies included education, health care, construction, and financial intermediation. China's results differ significantly because of its concentration of economic activity on the primary/secondary sectors. The results can enable identification of key intervention pathways along which sustainable development could be stimulated. Country-specific recommendations and reflections on economic and sustainability policy initiatives are discussed.

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1. Introduction

There is no one-size-fits-all approach to sustainable economic development that can be applied to every country, region, and city in the world. In the face of anthropogenic climate change, depletion of natural resources, dependence on fossil fuels, loss of biodiversity, and worsening socio-economic inequality; every region that intends to address these issues must tailor its sustainable development strategy in a way that considers its own unique set of economic, social, and environmental circumstances. Environmental protection and social well-being are global, not localized, issues that can only be effectively addressed in an international, coordinated manner. Global initiatives have been designed and undertaken to align different nations' sustainable development efforts towards agreed-upon goals, most notably and recently the 2015 Paris Agreement, which has been signed by 195 countries. The primary aim of the Paris Agreement is to mitigate anthropogenic climate change and ultimately hold global temperatures below 1.5 degrees Celsius above pre-industrial levels; a goal which will require careful consideration of direct and indirect GHG emissions resulting from industrial economic activity [1] (Savaresi, 2016). This paper aims to demonstrate a quantitative framework that can help individual countries most effectively identify how to sustainably manage their economies through key sector analysis, and explain the nature and causes of differences between key sectors across different countries. The six countries analyzed in this study are Austria, China, France, Germany, Sweden, and the USA. These countries were selected due to characteristics pertaining to their energy generation mix, degree of economic development, and social structure, among other factors that are further detailed in Section 2.4.

Understanding the complex internal structure of an economy allows one to gain a clearer picture of the nature and implications of its natural resource throughput as well as its impact on the wider social structure. Input-output analysis (I-O) is a simple yet powerful way of understanding the interdependencies of different components of an economy. EE I-O allows one to quantify the direct and indirect effects of economic activity on environmental and social indicators (CO₂ emissions and employment, respectively, in this study). The EE I-O method of key sector analysis is fundamental to gaining a clearer understanding of an economic structure and is employed to analyze the economies of the six countries. Key sectors can be calculated by different weightings, which in this case are different sectors' propensity for stimulating economy-wide final demand, CO₂ emissions, and employment as measured by forward and backward linkage coefficients. Using the MCDA method ELECTRE III, the forward and backward linkages are then used as criteria to form an outranking hierarchy, at the top of which is a proxy for the most sustainable sectors in each economy. The implications of these findings for the six countries is explored in a policy discussion, and this methodology could be extended to any number of countries in order to most optimally design their approach to sustainable development.

2. Methodological Literature Review

In this section the theoretical underpinnings, history, and recent applications of I-O, EE I-O and MCDA are explored. The justification for selecting each of the six countries is also described. There are large bodies of existing literature for EE I-O and MCDA, and this study aims to make a valuable contribution to that body of work by performing a comparative macro sustainability analysis using the novel framework which combines both key sector identification using EE I-O and MCDA in this manner.

2.1. Input-Output Analysis

The flow of resources into, within, and out of a region's economy involves several fundamental components including domestic economic sectors that produce and consume output (intermediate producers/consumers); households and the government that consume output (final consumers); and foreign nations that import and export goods and services into/out of the country. I-O is concerned with the intermediate sectors in an economy and the portions of their output that are then consumed by other intermediate sectors as inputs. The core element of an I-O model is a matrix showing resource flows (usually monetary) between economic sectors over a certain period of time (usually one year) [2] (Leontief, 1986). I-O, as a field of study, was developed by Russian-American economist Wassily Leontief, for which he won the 1973 Nobel Prize in Economics. Leontief was the first to represent intersectoral transactions as a matrix. Although his work resulted in the proliferation of the study and applications of I-O, important work by several others preceded him including Francois Quesnay's *Tableau économique* in 1758 [3] (He, 1972), and Léon Walras's *Elements of Pure Economics* in 1874 [4] (Walras, 2010). Balanced, symmetric I-O tables are derived from non-symmetric supply and use tables using methods including those outlined by [5] Eurostat (2008). The granularity of sector classification is arbitrary, and I-O tables are generated and used at a variety of sectoral resolutions (for example, the Electricity sector can be included as a whole, or it can be split into electricity generated from different sources such as coal, natural gas, nuclear, and renewables).

A variety of useful insights can be derived from I-O tables that reveal the structure of an economy and the interdependent relationships between its economic sectors. Leontief conceived the Leontief Inverse Matrix L , which is calculated as $(I - A)^{-1}$ where I is the identity matrix and A is the coefficients matrix (each value z in the I-O matrix as a proportion of its total output) [2] (Leontief, 1986). The Leontief Inverse has served as the basis for extensive applied economic analysis since it was first developed. Leontief's breakthrough and seminal work on the subject was his 1941 book *"The Structure of the American Economy, 1919–1939: An Empirical Application of Equilibrium Analysis"* [6] (Leontief, 1941). In this work he validated, using 10-sector balanced input-output tables that were

assembled using empirical data, that the general coefficient structure of the I-O tables was relatively stable over time, providing encouraging evidence that he had discovered a robust, accurately descriptive economic framework. In 1944, Leontief published “*Output, Employment, Consumption, and Investment*” [7] (Leontief, 1944), which applied I-O to the economic consequences of WWII. I-O was found to be practically useful to the degree that the United States Bureau of Labor Statistics adopted I-O as its preferred method of employment analysis following the war, and the government constructed a high-resolution I-O table that included 400 sectors [8] (Dorfman, 1973). Numerous other practical applications of I-O have emerged in the decades following Leontief’s pioneering work and it has become a key method used in a variety of economic contexts around the world including tourism impact [9] (Fletcher, 1989), interregional trade analysis [10] (Moses, 1955), and evaluating the structure of income distribution [11] (Miyazawa, 2012), among many others.

A key concept in I-O that was developed as an extension to Leontief’s work is forward and backward inter-industry linkages, which was a concept first introduced by Rasmussen [12] (1956). Forward and backward linkages are coefficients derived from the Leontief Inverse Matrix that measure the ‘downstream’ and ‘upstream’ direct and indirect influences of the activity of a particular sector on other sectors in an economy. To illustrate this in a simplified way, suppose an economy consists of three sectors; Agriculture, Manufacturing, and Transportation. Inputs into Agriculture include services provided by Transportation, which itself requires inputs from the Manufacturing sector, and so on. Therefore, expansion of the Agricultural sector results in indirect upstream expansion of both the Transportation and Manufacturing sectors. The degree to which this is the case is the backward linkage coefficient, and the same principle applies to forward linkages with downstream, consuming sectors. This methodology can be used to identify key sectors, which was an idea first proposed by [13] Hirschman (1958). Key sectors are those which have forward and backward linkage coefficients that are both greater than one, i.e., the sector is more deeply linked on average, in both directions, than all of the other sectors in the economy. Hirschman postulated that economic growth occurs primarily due to these key sectors and their above-average influence on the rest of the economy.

This was the concept underpinning unbalanced growth ([14] Akamatsu, 1961; [15] Hirschman and Lindbolm, 1962; [16] Hansen 1965). The concept of key economic sectors and linkages was further developed in a series of papers by Miyazawa ([17] Miyazawa, 1960; [18] Miyazawa, 1966; [19] Miyazawa, 1968; [20] Miyazawa, 1971) which focused on multi-regional economic systems and income multipliers. Michael Sonis and his colleagues have developed and expanded upon key economic sectors and linkages further, specifically focusing on hierarchies of key linkages/pathways and multiplier product matrices ([21] Sonis and Hewings, 1989; [22] Hewings et al., 1989; [23] Sonis and Hewings, 1992; [24] Sonis et al., 1995; [25] Israilevich et al., 1997; [26] Hewings et al., 1998; [27] Sonis et al., 2000; [28] Okuyama et al., 2004; [29] Guilhoto, Sonis and Hewings, 2005). Contemporary work in input-output analysis has included I-O database construction workflows in virtual laboratories ([30] Geschke and Hadjikakou, 2017; [31] Rahman et al., 2017; [32] Wiedmann, 2017), analyzing temporal changes in input-output networks ([33] Avelino, 2017; [34] Ye et al., 2017), and supply chain analysis ([35] Thekdi and Santos, 2016; [36] Baldwin and Lopez-Gonzalez, 2015).

2.2. Environmentally Extended Input-Output Analysis

Environmentally extended input-output analysis (EE I-O) builds upon I-O and is an analytical technique that aims, broadly, to calculate the hidden, indirect, or embodied environmental and/or social impacts associated with an upstream economic event ([37] Kitzes, 2013). EE I-O incorporates sectoral-level data on resource flows and usage (such as CO₂ emissions and employment) in order to calculate direct and indirect intensity of these flows in response to supply/demand stimuli. It has been conceptualized as a tool to present the complexity of economy-environment interactions by Daly [38] (1968), Ayres & Kneese [39] (1969) and Victor [40] (1971).

EE I-O can be used to determine key paths, sectors, and linkages in an economy for environmental, economic, or social indicators ([41] Lenzen, 2003; [42] Shmelev, 2012; [43] Shmelev, 2019).

Leontief was the first to extend input-output models to account for environmental impact and other resource use/emissions types in his 1970 paper *“Environmental Repercussions and the Economic Structure: An Input-Output Approach”* ([44] Leontief, 1970). In this paper he calculated technical input-output coefficients in order to analyze how growth in hypothetical economic sectors affected levels of corresponding pollution. Leontief and Ford created the first empirical EE I-O analysis of pollution using a 70-sector input-output table of the United States ([45] Leontief and Ford, 1971). Shortly afterwards, Leontief compared the nature of EE I-O characteristics in developed vs. developing countries ([46] Leontief, 1974). Further environmental extensions included those focused on energy and carbon emissions: [47] Carter (1974), [48] Carter (1976), [49] Herendeen & Tanaka (1976), [50] Proops (1977), [51] Park (1982), [52] Proops (1984), [53] Gay & Proops (1993), [54] Polenske & Lin (1993); [55] Minx et al. (2009), [56] Peters et al. (2011); water pollution: [57] Anderson & Manning (1983), [58] Lenzen and Foran B. (2001), [59] Dietzenbacher & Velázquez (2007), [60] Lenzen (2009); waste and resources: [61] Leontief (1977), [62] Duchin (1990), [63] Duchin (1994), [64] Ferrer and Ayres (2000), [65] Nakamura (1999), [66] Nakamura & Kondo (2002), [67] Hoekstra and van den Bergh (2002), [68] Suh (2005), [69] Kondo & Nakamura (2005), [70] Dietzenbacher (2005), [71] Nakamura & Kondo (2006).

Subsequent key methodological and interdisciplinary contributions were made by incorporating time-series data [72] (Barker, 1981) and MCDA ([73] Kananen et al., 1990; [74] Luptáčík and Böhm, 1994). Contemporary work in the field of EE I-O has included identifying key points of consumption that drive the emissions of particularly harmful substances such as PM_{2.5} ([75] Nagashima et al., 2017); assessing the sustainability of global supply chains ([76] Acquaye et al., 2017), and evaluating the consequences of food waste ([77] Reutter et al., 2017).

EE I-O is closely related to, and has heavily influenced and informed, the field of industrial ecology, which is the study of material and energy flows through industrial systems ([78] Ehrenfeld and Gertler, 1997; [79] Erkmann, 1997; [80] Frosch, 1992; [81] Graedel and Allenby, 2010; [82] Jelinski et al., 1992; [83] Thomas, 1997). It has also informed the development of material flow accounting (MFA), which is the study of material flows on a national or regional scale ([84] Fischer-Kowalski et al., 2011; [85] Haberl et al., 2004; [86] Hinterberger et al., 2003; [87] Moriguchi, 1999); life cycle assessment (LCA), which is used to evaluate the environmental impacts of every stage of a product's existence (manufacturing, usage, disposal, etc.) ([88] Cabeza et al., 2014; [89] Hellweg and Canals, 2014; [90] Curran, 1996; [91] Guinée, 2001), and urban metabolism, which analyzes the flow of material and energy through cities ([92] Gandy, 2004; [93] Kennedy et al., 2011; [94] Niza et al., 2009; [95] Sahely et al., 2003).

More recent environmentally extended input-output contributions include studies by [96] Lenzen et al. (2012) who found that approximately 30% of global species threats (as represented by the IUCN red list) are due to international trade using EORA database. In their research that linked 25,000 species to more than 15,000 commodities produced in 187 countries and evaluated over 5 bln supply chains from the point of view of their biodiversity impacts, [96] Lenzen et al. (2012) found that USA, Japan, Germany, France, UK, Italy, Spain, South Korea, Canada are the top ‘net importers’ of biodiversity and Indonesia, Madagascar, Papua New Guinea, Malaysia, Philippines, Sri Lanka, Thailand, Russia, Cambodia, Cameroon are the top ‘net exporters’. Such analysis was possible through the links between the threatened species and implicated commodities traded in international markets. The issues of the macroeconomic impacts of individual lifestyles have been addressed in [77,97–99].

2.3. Multi-Criteria Decision Analysis

Once a sector's forward and backward linkage coefficients have been calculated and weighted by final demand, CO₂ emissions, and employment, MCDA can be used to bring that information together into one singular assessment of the most optimal trade-offs between those criteria. MCDA is a broad categorization of decision-making frameworks that allow alternatives to be compared to each other according to differing criteria which are often conflicting and incommensurable. MCDA is highly suitable to this application, where sectors serve as alternatives and their forward and backward linkages serve as criteria with which the alternatives are evaluated. MCDA was initially developed in the 1960s by Bernard Roy. Since then, several branches of methods have emerged over the subsequent decades ([100] Roy and Vanderpooten, 1996).

Types of MCDA include outranking methods such as ELECTRE ([101] Roy, 1978; [102] Roy, 1990), Analytical Hierarchy Process (AHP) ([103] Handfield et al., 2002; [104] Saaty, 2008; [105] Zahedi, 1986), goal programming ([106] Ignizio, 1976; [107] Lee, 1972), weighted sum models ([108] Marler and Arora, 2010; [109] Rowley et al., 2012), and NAIAD ([110] Munda, 1995; [111] Menegolo and Pereira, 1996; [112] Munda, 2005).

The applications of MCDA are numerous, and it has historically been employed extensively in a variety of fields such as health care ([113] Nutt et al., 2010; [114] Baltussen et al., 2010; [115] Diaby et al., 2013), energy ([116] Datta et al., 2011; [117] Shmelev and van den Bergh, 2016; [118] Terrados et al., 2009; [119] Wang et al., 2009), and environmental sustainability ([120] Omann, 2004; [121] De Luca et al., 2017; [122] Fernandes et al., 2017, [123] Shmelev, 2017). MCDA has been used in conjunction with EE I-O in some cases, most notably by [82] Kananen et al. (1990), who evaluated emergency management techniques in response to the propagation of economic and political shocks through the input-output network of the Finnish economy; [74] Luptáčík and Böhm (1994), who employed a multi-objective model which aimed to minimize factor costs to produce Gross National Product (GNP) and also minimize net pollution; [42] Shmelev (2012), who used environmentally-weighted forward and backward linkage coefficients in combination with NAIAD to determine which sectors in the UK economy were the most sustainable; [124] Shmelev and Rodríguez-Labajos (2009), who assessed intertemporal macro sustainability in Austria over a 25-year period; and [125] Shmelev (2011), who used MCDA to assess macro sustainability progress over time in Russia according the UN Sustainability Development Framework of Indicators.

For this study, ELECTRE III was selected. ELECTRE III is an outranking method that was developed by Bernard Roy [101] (Roy, 1978), which incorporates realistic decision-making parameters for different criteria scores, namely an indifference threshold (below which one is indifferent to two alternatives by a given criterion), preference threshold (above which one displays a clear preference for one alternative over another by a given criterion), and a veto threshold (above which, for a certain criterion, an alternative outranks another by all criteria) [126] (Figueira et al., 2005). ELECTRE III was selected for this study because it is an outranking method which clearly displays the preference structure of alternatives, and because its incorporation of the aforementioned thresholds lends to a more realistic modelling of a decision-making process beyond simpler methods such as the weighted sum. It is a robust method that uses a strong sustainability concept (due to its non-compensatory nature), as opposed to the weak sustainability concept used by more rudimentary MCDA methods such as AHP ([127] Cinelli et al., 2014). The concepts of weak/strong sustainability and how they relate to MCDA are explored further in [128] Boggia and Cortina (2010); [129] Myllyviita et al. (2013); and [124] Shmelev and Rodríguez-Labajos (2009).

2.4. Country Selection

Austria, China, France, Germany, Sweden, and the USA were selected for this study because of particular economic, environmental, and social traits of interest that they possess. A comparison of the six countries by two measures each of economic, environmental, and

social development indicators (as defined by the UK Office for National Statistics) ([130] Office for National Statistics, 2015) is shown below in Figure 1. These traits affect the structure of their economies in unique ways, and observing how these traits are revealed through descriptive EE I-O analysis could result in useful insights that policymakers can use to adapt sustainable development strategies to each of the countries. The justification for each country's inclusion in the study is set out below.

Austria was included because of the wide array of accurate data available ([124] Shmelev and Rodrigues-Labajos, 2009); the strong influence of the economy of neighboring Germany; and the importance of its primary sector compared to other similar, highly-developed countries.

China was selected due mainly to its relative concentration of economic activity in the primary and secondary sectors compared to the other countries analyzed. China has grown rapidly over the last (GDP growth was 3003.5% between 1990 to 2016, compared to the global average of 234.6%) ([131] World Bank, 2017); it is a highly CO₂ emissions-intensive economy; and it acts as a point of contrast to the other five countries which are comparatively similar to each other.

France was selected primarily to explore the effect of the country's high degree of reliance on emissions-free nuclear energy, which made up 76.9% of the country's electricity generation in 2007 ([132] World Nuclear Association, 2017), the year of the EXIOPOL I-O data used in this study.

Germany is a highly CO₂ emissions-intensive economy with a strong focus on its manufacturing sectors relative to other highly developed western nations; particularly its automotive manufacturing sector. Oil and coal supply 58.4% of the country's energy demand, compared to the EU average of 51.9% ([133] BP, 2016). Germany has ambitious plans to decarbonize its economy, as outlined in its government's 'Climate Action Plan 2050' ([134] Government of Germany, 2016).

Sweden, in contrast to Germany, relies on hydroelectric power plants to supply 27.0% of its energy demand, compared to the global average of 6.9% ([133] BP, 2016). It generated 46.1% of its electricity from nuclear energy in 2007, in comparison to the aforementioned French figure ([132] World Nuclear Association, 2017). It is one of the least CO₂ emissions-intensive economies in the developed world, with CO₂ emissions per capita at 4.6 metric tons compared to the OECD average of 9.7 metric tons ([131] World Bank, 2017). The importance of the government, health care, and other public services to the economy of Sweden is also interesting to explore and contrast to the other countries.

Figure 1. Comparison of the six countries by select economic, environmental, and social indicators (World Bank, 2016; BP, 2016; CIA, 2016).

The USA is included because of its size and global significance. The country made up 24.6% of global GDP in 2016 ([131] World Bank, 2017). The USA differs in nature to the other five countries in several key ways, namely that it has much higher GDP per capita and CO₂ emissions per capita (Figure 1) and it has a much larger focus on public administration and defense. Its Gini coefficient is also high relative to the other highly-developed nations, implying that its vast wealth is particularly skewed towards the top of its socio-economic hierarchy.

Exploring differences in key sectors between these six countries will help to shed new light on the nature of their differences, provide insight into how sustainable development strategy should be adapted to meet the unique conditions of each nation, and also strengthen the robustness of environmentally extended input-output analysis as a tool for gaining accurate, data-driven insights into complex economies.

3. Methodology and Data Collection

3.1. Selecting a Data Source

To effectively compare and contrast the six countries, a set of standardized I-O tables with corresponding sectoral final demand, CO₂ emissions, and employment vectors were required. Many national governments compile and publicly release their own supply, use, and input-output tables along with labour statistics, but rarely do two countries' sector classifications align without some degree of modification or disaggregation. Fortunately, there are a number of sources of aggregated and standardized national input-output tables with corresponding environmental and resource accounts for multiple countries, five of which are compared in Table 1.

Table 1. Comparison of aggregated input-output data sources.

	OECD	EORA	GTAP	WIOD	EXIOBASE
Reference	[135–137] OECD, 2015	[138] Lenzen et al., 2013	[139] Aguiar et al., 2016	[140] Timmer et al., 2012	[141] Tukker et al., 2013
Years of data available	1995–2011	1990–2013	2004, 2007 and 2011	1995–2011 (I-O Tables) 1995–2009 (Environmental/social accounts)	2000, 2007
Number of regions	61	186	147	40	43
Number of sectors	34	26–>1000	57	37	163
Corresponding resource accounts	Air emissions, employment.	Energy use, GHG and other air emissions, land use, water use, employment, crop/livestock use, fertilizer use Inconsistent across regions and years. Uses each country's native classification systems. Mix of SUT and IOT across commodities, industries, and both. Considerable amount of estimated figures	Energy, CO ₂ emissions, labour data	Large range of emissions accounts and socioeconomic indicators.	15 land use types; Employment per three skill levels; 48 types of raw materials; 172 types of water uses
Industry classification consistency and other considerations	Fully consistent across input-output tables. Environmental and social accounts do not match up perfectly.		Consistent across countries and years. Focus is on analysis of international trade	Consistent across countries and years.	Consistent across countries and years.

EXIOPOL was selected as the data source for this study because:

1. It contains standardized, symmetric input-output tables for Austria, China, France, Germany, Sweden, and the USA;
2. It contains complete data for final demand as well as sector-disaggregated CO₂ emissions and employment accounts;
3. It has a very high sectoral resolution (163 sectors) including separate categories for different types of electricity generation and waste management.

A disadvantage to using EXIOPOL is that the most recent data available is from 2007, whereas other sources have more up-to-date data. This fact is outweighed by the benefits listed above and does not affect the ability to illustrate this study's methodology. EXIOPOL's wide array of environmental and resource accounts are not based entirely on empirical data because of information availability limitations. The process for calculating and disaggregating the environmental accounts used in EXIOPOL is described in [13] Tukker et al. (2013). For the purposes of this study the data is sufficient to illustrate the usefulness of the method and to make reasonably accurate calculations of the CO₂ emissions and employment forward and backward linkage coefficients.

3.2. Calculating Forward and Backward Linkage Coefficients

To calculate the forward and backward linkage coefficients for each industry weighted by each resource vector, the methodology used in Manfred Lenzen's 2003 paper '*Environmentally important paths, linkages and key sectors in the Australian economy*' was employed ([41] Lenzen, 2003). The forward linkage is the resource-weighted row average of the Leontief inverse L , which is then divided by the resource-weighted global average of L . The forward linkage is the resource-weighted column average of the Leontief inverse L , which is then divided by the resource-weighted global average of L .

A linkage coefficient represents how deeply linked a sector is relative to all of the linkages in the economy. For example, a sector with a forward CO₂ linkage coefficient of 1.5 is 50.0% more linked than the average of all sectors in the economy. A key sector is one which has both a forward and backward linkage greater than one, implying that it has an above-average ripple effect on economy-wide final demand, CO₂ emissions, or employment in response to stimulus/contraction in that sector.

3.3. Calculating Sector Sustainability with Multi-Criteria Decision Analysis

After the linkage coefficients were calculated for final demand, CO₂ emissions, and employment, an MCDA using ELECTRE III was used to determine which sectors have the most optimal balance of forward and backward linkage coefficients for the three categories. The intended output of this calculation is a proxy for the most sustainable economic sectors in the country in question. There are established methods in the literature that guide selection of realistic values for the indifference, preference, and threshold levels, which is inherently a highly subjective process. One such guideline is [142] Rogers and Bruen (1998a), which suggests that (a) the veto threshold v should be set closer to the preference threshold as adverse human reaction to the criteria increases and (b) that the preference threshold p and the indifference threshold i should be defined within relatively strict limits.

The threshold settings for this study are shown in Table 2. The thresholds were determined as a proportion of the difference between the highest and lowest linkage coefficients for each criteria. Indifference thresholds were set at 1.0% of the difference, preference thresholds were set at 1.1% (reflecting the first of Rogers and Bruen's [142] principles) and veto thresholds were set at 80.0% of the difference for final demand and employment, and 70.0% of the difference for CO₂ emissions (conforming to Rogers and Bruen's [142] second principle). Setting the indifference and preference thresholds so close together follows the concept of strong sustainability because there is a very small degree of compensation among criteria.

Table 2. Criteria thresholds and goal settings for the China ELECTRE III MCDA calculation.

Criteria	Max Linkage Coefficient	Min Linkage Coefficient	Difference (Max–Min)	Indifference Threshold (i)	Preference Threshold (p)	Veto Threshold (v)	Goal
Final demand, forward linkage	18.15	0	18.15	0.18	0.2	14.52	Maximise
Final demand, backward linkage	14.09	0	14.09	0.14	0.16	11.27	Maximise
CO ₂ emissions, forward linkage	27.36	0	27.36	0.27	0.3	19.15	Minimise
CO ₂ emissions, backward linkage	9.79	0	9.79	0.1	0.11	6.85	Minimise
Employment, forward linkage	9.05	0	9.05	0.09	0.1	7.24	Maximise
Employment, backward linkage	9.27	0	9.27	0.09	0.1	7.42	Maximise

All six criteria were equally-weighted at 16.67% each. Because of the volume of data produced for the six countries, different weighting schemes were not evaluated in this study due to scope constraints. Utilizing unequal weighting schemes is a direction for future research in this context.

4. Results

4.1. Forward and Backward Linkage Coefficients

Figures 2–7 show key sectors and forward/backward linkage coefficients weighted by final demand, CO₂ emissions, and employment. Key sectors (those with forward and backward linkages greater than one) are highlighted in orange. Two countries are compared for each weighting scheme, and the complete coefficient results can be found in Appendices A and B. The countries in the following comparisons were chosen because of the nature in which their results contrast for different weightings.

Figure 2. Final demand-weighted forward and backward linkages (USA).

Final demand key sectors in the USA are largely centered on the services/tertiary industries, with 18 tertiary sectors out of a total of 25 key sectors. *Public administration and defence* is deeply linked within the USA economy because of the government's high degree of military expenditure, which totaled 3.3% of its GDP in 2016 compared to the global average of 2.2% of GDP ([131] World Bank, 2017). *Real estate activities*, *Health and social work*, and *Construction* rounded out the other most deeply linked sectors. Deeply linked secondary sectors in the USA include *Construction*, which is typical of most countries in this study and *Manufacture of motor vehicles, trailers and semi-trailers*, due to the USA's status as the second-largest motor vehicle producer in the world after China.

In contrast to the USA, Germany's economy has more key sectors in the secondary/manufacturing field (Figure 3). With 14 primary/secondary sectors out of a total of 29 key final demand sectors. Of note is the deep linkage of the *Manufacture of motor vehicles, trailers and semi-trailers* sector. Automotive manufacturing comprised 20.0% of total industry revenue and employed nearly 800,000 people in Germany in 2015. It is also the most central sector overall to the German economy from a network analysis standpoint ([143] Blöchl et al., 2011). The most deeply linked final demand sector in Germany is *Real estate activities*, with *Health and social work*, *Construction*, *Public administration and defence*, and *Education* also strongly linked. *Public administration and defence*, although a key sector, is not as deeply linked as it is in the USA. Government military expenditure in Germany is 1.2% compared to 3.3% in the USA ([131] World Bank, 2017).

Figure 3. Final demand-weighted forward and backward linkages (Germany).

In Austria, coal and natural gas supply 36.0% and 22.4% of total energy consumption, respectively ([133] BP, 2016). This is reflected in Figure 4 that as they are both deeply linked sectors as weighted by CO₂ emissions. Manufacturing industries also have strong linkages throughout the Austrian economy, such as *Manufacture of basic iron and steel and of ferro-alloys and first products thereof*, *Manufacture of gas; distribution of gaseous fuels through mains*, and *Manufacture of cement, lime and plaster*. Of note are sectors with very high backward linkages and forward linkages of zero, which are renewable energy generation sectors (*Production of electricity by Geothermal*, *Production of electricity by solar photovoltaic*, *Production of electricity by wind*, and *Production of electricity not elsewhere classified*). This phenomenon is unique to Austria among the six countries studied, and is important to note as the true indirect impact of renewables on CO₂ emissions in Austria may be significantly higher than previously thought.

Figure 4. CO₂ emissions-weighted forward and backward linkages (Austria).

By comparison, the key CO₂ emissions sectors in France are shown in Figure 5. This structure is quite different than that of Austria. Because France generated 76.9% of its electricity from nuclear energy in 2007 ([132] World Nuclear Association, 2017), electricity generation sectors tend to be less deeply linked in its economy weighted by CO₂ emissions. This contrast is even more striking when compared to coal-focused economies such as Germany, the USA, and China.

The effect of *Sea and coastal water transport* is apparent compared to landlocked countries such as Austria. *Other business activities* have an unusually high forward CO₂ emissions-weighted linkage, due mainly to its strong downstream linkages CO₂ emissions-intensive sectors such as *Sea and coastal water transport*; *Inland water transport*; and *Manufacture of cement, lime and plaster*.

Figure 5. CO₂ emissions-weighted forward and backward linkages (France).

As can be seen in Figure 6, Sweden's workforce is largely centered around the tertiary/services sectors, with *Health and social work*, *Education*, and *Public administration and defence; compulsory social security* employing 31.9% of the workforce ([141] Tukker et al., 2013).

Other industries that are deeply linked include *Other business activities*, *Construction*, and *Wholesale trade*. Sweden is the only country where *Health and social work* has the highest forward and backward employment linkage coefficients. This is likely because of strong state support for healthcare and other public services in Sweden. Health expenditure as a percentage of GDP is 11.9% in Sweden, which is the second-highest out of all OECD countries apart from the USA, which spends 17.1% of GDP on healthcare ([131] World Bank, 2017), although that spending is of a different nature.

Figure 6. Employment-weighted forward and backward linkages (Sweden).

In stark contrast to Sweden, as well as to the other countries analyzed, China's labour force is largely focused on the primary and secondary production and manufacturing sectors (Figure 7). China's primary and secondary sectors employ 67.6% of its workforce, compared to 25.1% in Sweden ([141] Tukker et al., 2013). Of note are the strong backward linkages in meat production and processing in China. *Production of meat pigs* has a backward employment linkage of 9.27 due primarily to it drawing inputs from employment-heavy sectors such as *Pigs farming*; *Wholesale trade*; and *Cultivation of vegetables, fruit, nuts*. China's uniqueness among the other nations included in this study is clearly identifiable in these results and will be further elaborated upon in the following sections of this study.

Figure 7. Employment-weighted forward and backward linkages (China).

Figures 8 and 9 visualize the dispersion of linkage coefficients in France and the USA in three dimensions, with the average CO₂ linkage on the x-axis, the average final demand linkage on the y-axis, and the average employment linkage encoded in the size of the circles. One can start to gain a sense of which sectors are the most sustainable by observing which sectors cluster near the top-left of the charts and have large circles indicative of high average employment linkage coefficients. Less sustainable sectors cluster near the bottom-right of the chart and have small circle sizes/low employment linkages. The remaining linkage coefficient trade-off charts can be found in Appendix C.

Figures 8 and 9 show distinct differences between France and the USA. In France, *Real estate activities*; *Construction*; *Health and social work*; and *Public administration and defence* cluster towards the top-left of the chart indicating their high degree of overall sustainability. The bottom-right of the chart includes less sustainable sectors such as *Manufacture of basic iron*; *Production of electricity by coal*; and *Air transport*. In the USA, the scale of the x-axis extends past 28.0 to accommodate the extremely high CO₂ emissions linkages from the *Production of electricity by coal* sector. More sustainable sectors in the USA appear to be *Health and social work*; *Real estate activities*, and *Construction*. *Public administration and defence*, although it appears to cluster at the top-left of the figure, has very high forward and backward CO₂ linkage coefficients of 4.50 and 2.71, respectively. The USA military is thought to be the largest single institutional emitter of GHGs in the world, and it emitted

over 70 million tons CO₂-equivalent in 2016 (excluding foreign bases and operations) ([144] U.S. Department of Energy, 2017).

4.2. Sector Sustainability Rankings

Table 3 below shows the results of the ELECTRE III calculations. The five most and least sustainable sectors in each country according to the six linkage criteria are shown. They are ranked according to how many other sectors in the economy that they dominate with a cutoff proportion of 0.8. The full rankings for all 163 sectors can be found in Appendix D.

The results of the MCDA show many similarities between the six countries, as well as some prominent differences. Education is in the top three sustainable sectors for all six countries. *Health and social work* is in the top three for all countries except for China. *Financial intermediation* appears in the top five for all countries except for China. China's top five most sustainable sectors are mostly comprised of primary and secondary industries due to the concentration of its final demand and labour force in those portions of the economy. Of note is the peculiar presence of both *Mining of coal and lignite; extraction of peat* and *Processing of meat pigs* in the top five most sustainable sectors in France. While these results seem erroneous at first, they are explained by unexpectedly high backward linkage coefficients to key final demand and employment sectors. In the case of *Mining of coal and lignite; extraction of peat*, the sector has strong backward linkages with (i.e., it draws heavily on for inputs) final-demand and employment heavy industries such as *Other business activities; Financial intermediation, except insurance and pension funding; and Computer and related activities*. Its forward and backward CO₂ emissions linkages are both practically negligible, therefore it is considered much more sustainable, as calculated using this dataset, than it would seem at first glance. *Processing of meat pigs* has very strong backward linkages to *Other business activities* and *Wholesale trade*, which explain its high ranking in France's sustainability hierarchy. The EU's Common Agricultural Policy subsidy program could also play a role in this result. The possibility exists that these unexpected results are due to some degree of empirical inaccuracy in the data; however, the fact that their presence can be explained clearly by linkage coefficients is promising for this method's capability of eliciting and justifying unexpected and potentially valuable new insights.

The least sustainable sector results also share many similarities across the six countries. *Production of electricity by gas and coal* appear frequently, as would be expected due to their high CO₂ emissions intensities. China's results were more similar to those of the other five countries than they were for the top five most sustainable sectors, however the presence of *Collection, purification and distribution of water* on the list of least sustainable sectors is notable. This is due to it drawing large amounts of input from *Production of electricity by coal* and *Steam and hot water supply*, which are both highly CO₂-intensive in China. In France, both *Air transport* and *Sea and coastal water transport* are relatively unsustainable due to their very high CO₂ emissions forward and backward linkages and the sectors' relatively insignificant effects on final demand and employment. In Sweden, *Production of electricity by biomass and waste* is highly unsustainable due to that same set of characteristics.

Figure 8. Trade-off of average forward and backward linkage coefficients (France).

Figure 9. Trade-off of average forward and backward linkage coefficients (USA).

Table 3. Five most sustainable sectors by country, by number of other sectors outranked.

Country	Rank	Sector
Austria	1	Other service activities
	2	Health and social work
	3	Education
	3	Public administration and defence; compulsory social security
China	1	Education
	2	Public administration and defence; compulsory social security
	3	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing
France	1	Health and social work
	2	Education
	3	Processing of meat pigs
Germany	1	Health and social work
	2	Education
	3	Hotels and restaurants
Sweden	1	Health and social work
	2	Education
	3	Hotels and restaurants
USA	1	Education
	2	Health and social work
	3	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts ...

5. Discussion

5.1. Differing Economic Structures of the Six Countries

The results of the above analysis reveal as many similarities between the six countries as they do differences. Many of the countries share key sustainable sectors, and the implications of any differences in economic structure can be drawn by comparing the five highly-developed, western countries (Austria, France, Germany, Sweden, and the USA) to China, which is still rapidly developing and has a greater economic focus on its primary and secondary industries. Sectors appearing at or near the top of the MCDA hierarchies for most of the five western countries include *Health and social work*; *Education*; *Financial intermediation, except insurance and pension funding*; *Insurance and pension funding, except compulsory social security*; *Hotels and restaurants*; *Computer and related activities*; and *Other service activities*.

These sectors contribute greatly to final demand and therefore economic growth while employing the largest portions of the countries' workforces. Sectors appearing most frequently at the bottom of the MCDA hierarchies in these countries are generally those associated with electricity production using fossil fuels and extractive industries, particularly mining of metals and ores. *Air transport* is also quite unsustainable in these countries due to that industry's enormous usage of fossil fuels which result in high amounts of CO₂ emissions. By comparison, China's most sustainable sectors contain some of the tertiary industries found at the top of the MCDA in the five western countries, however agricultural and other primary/secondary sectors play more important roles in China, comparatively. The most sustainable sectors in China include *Education*; *Public administration and defence; compulsory social security*; *Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing*; *Cultivation of vegetables, fruit, nuts*; *Processing of Food products nec*; and *Manufacture of fish products*, many of which are primary and secondary sectors. The tertiary sectors only account for 37.2% of China's total final demand and 32.4% China's of total employment. This is about half of the equivalent figure in the other five countries, on average. A breakdown of the broad final demand and employment structures of the

six countries can be seen in Figure 10. Of note is China's heavy employment focus on its primary agricultural/extractive industries, which comprise 42.1% of total employment, although they contribute only 6.0% of final demand.

Figure 10. Industry make-up of final demand and employment across the six countries.

5.2. Policy Implications

The insights gained from this study could be highly useful to policymakers who are formulating green economy and investment policies. First, it can offer guidance on where to focus the greening efforts by identifying sectors that are either clearly unsustainable, or are highly economically beneficial but do not have strong linkages with employment and are particularly harmful in their indirect effects on the environment. A list of such 'pitfall' industries is shown below in Table 4, which shows the list of sectors that have a strongly positive impact on the economy in terms of final demand, but are not particularly beneficial in terms of employment and have above-average upstream and downstream CO₂ emissions linkages. These are distinguished from the most unsustainable sectors, as many of those tend not to be economically-attractive sectors.

Table 4. Pitfall sectors in the six countries (those with above-average final demand linkages; above-average CO₂ emissions linkages; and below-average employment linkages).

Austria	China	France	Germany	Sweden	USA
Processing of Food products nec	Distribution and trade of electricity	Processing of Food products nec	Petroleum Refinery	-	-
Transmission of Electricity		Chemicals nec			
Distribution and trade of electricity					
Air transport					

Actionable steps that can be taken by policymakers from the results of this study include designing or re-designing economic development and investment plans around the sectors that are the most and least sustainable. The methodology used is flexible and could evolve continually to incorporate new data and shifting objectives, which is important considering sustainable development strategy should be highly dynamic and adaptable ([145] El-Erian and Spence, 2008).

Each of the six countries has ratified the 2015 Paris Agreement. In addition to this shared objective, they also have clearly defined sustainable development strategies, which could benefit to some degree from insight gained using this study's methodology. The Austrian government has long displayed its commitment to environmental protection through successful pollution reduction initiatives, relatively high environmental spending as a proportion of GDP, and a commitment to future green growth through its '*Masterplan Green Jobs*' and '*Growth in Transition*' initiatives ([146] OECD, 2013). Its policy support for renewable energy is strong with 100% of electricity in its largest state, Lower Austria, now being generated from renewables ([147] France-Presse, 2015). China has historically been one of the most environmentally-impactful nations on earth due to severe air pollution resulting from industrial activity ([148] Chan and Yao, 2008; [149] Feng, 1999). However, its government has adopted more environmentally-friendly policies in recent years, with renewable energy near the forefront of that focus ([150] Xiao et al., 2017; [151] Zhao and Luo, 2017). China planned to invest £292 billion into renewable power by 2020 ([152] Reuters, 2017). France has ambitious sustainable development targets including those outlined in its 2015 '*Energy Transition for Green Growth Act*' and its role as a driving force in the formulation and international adoption of the Paris Agreement ([153] OECD, 2016). However, France still relies heavily on nuclear energy, although that reliance is falling. Its percentage of electricity generated from nuclear came down from 78.1% in 2006 to 72.3% in 2016 ([132] World Nuclear Association, 2017). Germany is highly ambitious in its plans to decarbonize its economy, particularly as it relates to renewable energy policy. Ultimately, it hopes to reduce its total GHG emissions by 80% to 95% by 2050 as per its '*Climate Action Plan 2050*' ([134] Government of Germany, 2016). At present, Germany's economy is highly CO₂-intensive and there is much potential for improvement which could be streamlined by identifying and growing key sustainable sectors. Sweden is perhaps the most environmentally successful of the six countries due to its government's highly ambitious policy support for sustainability, which has resulted in drastic GHG emissions reductions in recent decades ([146] OECD, 2013). Its proximity to the Baltic Sea and the issues surrounding overfishing in that region will continue to be a primary concern for Sweden in the future ([154] Lindegren et al., 2009). The USA currently faces major challenges to its policy support for sustainable development due to actions by its current federal government that include proposed funding cuts to its Environmental Protection Agency ([155] Neslen, 2017) and efforts to increase domestic coal production and exports ([144] U.S. Energy Information Administration, 2017). It has also signaled its intention to withdraw from the Paris Agreement ([83] Thomas, 2017).

In spite of this, some individual states are pursuing their own ambitious sustainability and renewable energy policy targets. For example, California's "*2030 Climate Commitment*" aims to generate half of the state's electricity from renewables by 2030 ([156] State of California Energy Commission, 2015). The state of Oregon has also legislated a requirement for 50% of its electricity to be derived from renewables by 2040 ([157] Oregon Department of Energy, 2016).

6. Conclusions

In this study, EE I-O and MCDA have been employed to identify the most sustainable sectors out of a total of 163 sectors in six countries (Austria, China, France, Germany, Sweden, and the USA) according to their economic, environmental, and social impact. Specifically, forward and backward linkages based on the Leontief Inverse Matrices of the I-O tables were weighted by final demand, CO₂ emissions, and number of employees to

determine those sectors that had above average upstream and downstream impacts on the economy as a whole. The linkages for each country were then used as criteria in an MCDA calculation using the ELECTRE III method. This process created a hierarchy of dominant relationships between sectors that showed which sectors were most optimal in maximizing final demand and number of employees, whilst reasonably minimizing CO₂ emissions. The results for the six countries reflected the underlying fundamental differences in the structure and nature of these economies, and these differences are contrasted and assessed for their implications and significance to policymakers. Sectors that were most frequently identified as being highly sustainable in most or all of the six countries included *Education*, *Health and social work*, and *Hotels and restaurants*.

The least sustainable sectors included Production of electricity by gas, coal petroleum and other oil derivatives; mining of metals and other ores; Manufacture of cement, lime and plaster; and Air transport. Some sectors that were sustainable in some countries were highly unsustainable in others, and vice versa. Examples of this include Cultivation of crops not elsewhere classified, which is far more unsustainable in France than it is on average for the other countries; Financial intermediation, except insurance and pension funding, which is far more unsustainable in China than it is on average for the other countries; and Mining of aluminum ores and concentrates, which is far more sustainable in France than it is on average for the other countries. These results prove that there is no effective one-size-fits-all policy strategy for sustainable development that applies to all countries. Taking these coefficients into account can help individual nations optimize their pursuit of sustainable development so that collective international targets such as the Paris Climate Agreement can be met in the most efficient and effective way possible.

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Appendix A. Complete Forward and Backward Linkage Coefficients

Table A1. Complete forward and backward linkage coefficients for all six countries Key sectors where the forward and backward linkage are both greater than one are highlighted in green. An index of sector ID numbers and their corresponding full names can be found in Appendix D of this paper.

Sector ID	Austria						China					
	Final Demand		CO ₂		Employment		Final Demand		CO ₂		Employment	
	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd
1	0	0	0	0	0	0	0.57	0.21	0.58	0.48	2.49	1.32
2	0.07	0.69	0.15	0.35	0.42	0.81	0.38	0.23	0.15	0.36	1.38	0.83
3	0.21	0.66	0.44	0.54	0.98	0.92	0.5	0.31	0.22	0.44	1.67	1.03
4	0.46	0.81	0.43	0.58	1.13	1.11	3.06	2.08	0.7	0.52	9.05	5.76
5	0.04	0.37	0.07	0.18	0.09	0.38	0.32	0.19	0.15	0.29	1.39	0.86
6	0.02	0.7	0.04	0.26	0.08	0.7	0.22	0.14	0.14	0.17	1.37	0.89
7	0	0.02	0	0	0	0.02	0.09	0.25	0.06	0.43	0.74	0.66
8	0.22	0.8	0.08	0.34	1.25	1.13	0.71	0.54	0.13	0.21	2.92	1.88
9	0.11	2.17	0.15	1.07	1.21	2.91	0.23	1.46	0.19	0.54	0.82	1.66
10	0.25	0.85	0.07	0.38	0.79	1.29	1.36	1.41	0.54	0.38	5.31	4.01

Table A1. Cont.

11	0.15	0.71	0.01	0.34	0.27	0.85	0.65	1.78	0.21	0.52	1.35	2.17
12	0.08	0.07	0.02	0.02	0.04	0.06	0.15	0.93	0.03	0.26	0.8	1.25
13	0.08	0.07	0.01	0.02	0.04	0.06	0.24	1.44	0.04	0.41	0.5	1.61
14	0.32	0.52	0.16	0.24	1.3	1.07	0.29	1.11	0.16	0.74	0.7	1.37
15	0	0.51	0	0.23	0	0.58	0.01	0.78	0.01	0.32	0.06	0.78
16	0	0	0.05	0.04	0	0	0	0	0.01	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0.67	0.55	0.45	0.33	1.43	0.85	0.42	0.28	0.28	0.14	2.21	1.43
19	0.01	1.16	0	0.51	0.02	1.13	1.73	0.4	0.2	0.11	8.25	5.23
20	0	0.81	0	0.36	0	0.73	2.04	0.7	12.65	1.5	2.26	0.83
21	0.05	0.63	0.24	0.34	0.03	0.79	1.15	0.67	1.84	1.39	1.43	0.6
22	0.04	0.54	0.83	0.86	0.04	0.73	0.46	0.53	1.29	1.33	0.55	0.46
23	0	0	0	0	0	0	0	0	0.02	0.01	0	0
24	0	0	0	0	0	0	0.01	0.67	0	1.83	0	0.52
25	0.01	1.16	0.17	0.52	0.01	1.23	0.06	0.78	0.2	1.57	0.05	0.64
26	0	0	0	0	0	0	0.29	0.71	0.28	1.98	0.22	0.6
27	0	0	0	0	0	0	0.04	0.67	0.09	1.93	0.04	0.54
28	0	0	0	0	0	0	0.03	0.68	0.06	1.64	0.02	0.55
29	0	0	0	0	0	0	0.23	0.83	0.31	1.82	0.18	0.66
30	0	0	0	0	0	0	0.04	0.87	0.03	2.51	0.03	0.67
31	0.04	1.28	0.63	0.61	0.04	1.27	0.4	0.93	0.72	1.57	0.31	0.73
32	0.11	1.14	0.1	0.7	0.1	1.22	0.22	0.79	0.32	1.09	0.16	0.66
33	0.24	1.03	0.55	0.77	0.25	1	0.56	0.72	1.08	1.11	0.44	0.65
34	0.01	1.4	0.02	0.68	0.01	1.15	0.03	1.03	0.06	1.38	0.04	0.84
35	0.3	1.3	0.08	0.77	0.14	1.61	0.03	1.63	0.01	0.62	0.02	1.86
36	0.43	1.22	0.12	0.53	0.14	1.99	0.09	3.43	0.04	0.97	0.05	9.27
37	0.07	0.14	0.01	0.06	0.07	0.17	0.12	2.73	0.04	0.82	0.08	3.29
38	0.44	0.25	0.04	0.03	1.26	0.63	0.39	0.83	0.12	0.5	0.41	0.88
39	0.1	0.16	0.03	0.05	0.33	0.3	0.19	0.47	0.08	0.42	0.21	0.97
40	0.68	1.42	0.22	0.62	0.28	1.4	0.11	1.17	0.05	0.77	0.12	1.43
41	0	0.04	0	0.02	0	0.05	0.16	0.61	0.45	1.13	0.08	1.02
42	0.09	0.25	0.03	0.1	0.05	0.25	0.04	0.45	0.02	0.3	0.04	1.24
43	1.48	1.57	1.01	1.15	0.61	1.28	4.51	2.53	0.9	0.49	5.63	2.08
44	0.98	1.53	0.15	0.65	0.6	1.4	0.4	1.12	0.08	0.75	0.24	1.26
45	0.03	1.14	0.01	0.52	0.02	1.35	2.6	2.02	0.3	0.39	1.05	3.3
46	0.12	0.63	0.01	0.28	0.04	0.74	0.12	0.65	0.06	0.47	0.02	1.15
47	0.24	0.73	0.24	0.47	0.51	0.92	2.37	0.79	1.2	0.86	2.78	1.55
48	0.03	0.69	0.03	0.27	0.22	0.83	1.92	1.81	0.51	0.71	1.08	1.52
49	−0.02	0.8	0.04	0.4	0.14	1	0.78	0.9	0.35	0.56	0.73	1.19
50	1.36	1.14	0.91	0.81	1.57	1.37	0.12	0.23	0.12	0.48	0.11	0.52
51	0.26	0.97	0.12	0.52	0.34	1.07	0.01	0.21	0.01	0.51	0.01	0.23
52	0.15	0.79	0.2	0.81	0.42	1	0.01	0.66	0.03	1.44	0.01	0.73
53	0.06	0.79	0.71	1.08	0.2	0.94	0.01	0.69	0.04	1.1	0.01	0.64
54	0.39	0.88	0.23	0.57	0.39	1.05	1.1	0.64	0.84	0.97	1.27	0.86
55	1.44	0.98	1.97	1.47	2.07	1.22	1.42	0.7	0.79	0.78	1.82	0.97
56	0.05	0.62	2.61	2.17	0.03	0.72	0.46	0.82	2.94	1.74	0.47	0.76
57	0.97	0.72	4.31	3.13	0.45	0.49	3.81	0.55	4.97	0.91	4.17	0.63
58	0	0.69	0	0.25	0	0.78	0	1.75	0	1.06	0	0.92
59	0.77	0.8	1.09	1.03	1.01	0.95	0.51	0.66	0.49	1.02	0.6	0.74
60	0.02	0.55	0.01	0.31	0.02	0.65	0.04	0.73	0.03	0.98	0.05	0.77
61	0	0.57	1.92	1.96	0.01	0.61	0	0.48	1.01	1.18	0.01	0.49
62	0	0.57	0.03	0.44	0.01	0.61	0.54	0.49	0.54	0.92	1.93	0.55
63	0.13	0.94	0.85	1.24	0.17	0.95	5.38	1.09	4.66	1.63	5.06	1.02
64	0.69	0.92	0.45	0.51	1.26	1.25	3.99	0.86	2.55	1.19	4.46	1.64
65	0.04	0.67	0.17	0.48	0.04	0.75	1.59	0.67	0.73	0.97	1.16	0.77
66	0.01	0.66	0.13	0.46	0.01	0.73	0	0	0	0	0	0
67	0.05	0.7	0.04	0.39	0.07	0.74	1.67	0.69	0.15	1.13	0.99	0.92
68	0.11	0.81	0.98	1.21	0.1	0.81	0.05	0.65	0.43	1.35	0.02	0.61
69	1.48	0.98	5.97	4.83	1.63	1.28	0.68	0.66	8.54	4.91	0.3	0.72
70	0.05	0.88	1.67	2.32	0.05	0.97	0.12	0.65	1.54	1.94	0.05	0.67

Table A1. Cont.

71	0.15	0.76	0.42	0.69	0.17	0.8	1.17	0.73	1.35	1.83	0.75	0.77
72	0.07	0.45	10.32	8.7	0.39	0.64	6.11	0.59	19.81	6.65	4.39	1.14
73	0.04	0.49	5.4	4.81	0.25	0.61	1.34	0.6	3.6	3.67	0.99	0.77
74	0.02	0.45	0.08	0.22	0.03	0.51	0.45	0.75	0.53	1.37	0.28	0.59
75	0	0	0	0	0	0	0	0	0	0	0	0
76	0.21	0.62	1.46	1.64	0.29	0.75	1.22	0.7	1.22	2.05	0.87	0.64
77	0.01	0.62	0.07	0.71	0.02	0.77	0.03	0.7	0.03	1.09	0.03	0.57
78	0	0.41	0.08	0.57	0	0.49	0.32	0.53	0.23	0.99	0.17	0.44
79	0	0.42	0.04	0.56	0	0.5	0.03	0.53	0.02	0.84	0.02	0.42
80	0.14	0.52	0.14	0.41	0.18	0.61	0.8	0.49	0.52	0.99	0.43	0.43
81	0.02	0.51	0.03	0.42	0.03	0.58	0.11	0.48	0.12	1.03	0.06	0.4
82	0.13	0.82	4.23	3.57	0.15	0.8	0.68	0.88	0.93	1.41	0.42	0.67
83	0	0	0	0	0	0	0	0	0	0	0	0
84	0.41	0.56	2.17	1.35	0.43	0.65	0.56	0.78	0.66	1.86	0.36	0.73
85	2.78	1.46	1.12	0.62	3.31	1.76	3.04	1.06	2.62	2.69	2.28	1.14
86	2.62	1.64	1.29	0.66	3.27	1.97	8.01	4.06	4.51	1.85	4.39	1.84
87	0.03	0.85	0	0.31	0.04	0.89	1.58	1.19	1.35	0.68	1.21	0.91
88	1.38	1.09	1.08	0.68	1.61	1.32	4.69	2.2	3.76	1.72	2.48	1.18
89	0.55	0.88	0.14	0.41	0.71	1.03	1.52	1.07	0.62	0.75	1.42	1.06
90	0.55	0.85	0.16	0.32	0.82	1.1	0.43	0.77	0.2	0.73	0.44	0.73
91	1.23	1.02	0.31	0.37	1.15	1.04	4.12	3.36	1.79	1.62	2.28	1.65
92	0.62	0.81	0.3	0.36	0.48	0.85	2.49	2.23	1.12	1.87	1.74	1.15
93	1.14	1.19	0.33	0.49	1.39	1.4	2.96	1.81	1.06	0.93	2.18	1.77
94	0.06	0.72	0.79	0.59	0.12	0.79	0.78	0.07	1.26	0.15	0.62	0.1
95	0	0	0.03	0.02	0	0	0	0	0	0	0	0
96	0.11	0.68	7.29	8.02	0.11	0.61	3.21	0.87	27.36	9.79	2.76	0.75
97	0.35	0.46	11.04	10.03	0.23	0.33	0.05	0.5	0.57	1.19	0.04	0.41
98	0	0	0	0	0	0	0.07	0.33	0.08	0.2	0.06	0.25
99	0.51	0.68	2.83	2.13	0.48	0.61	0.57	0.44	0.64	0.3	0.47	0.31
100	0.02	0.68	0.05	2.23	0.02	0.56	0.01	0.4	0.01	0.28	0.01	0.28
101	0.06	0.62	1.25	4.58	0.04	0.42	0.06	0.59	0.33	0.96	0.04	0.49
102	0.17	0.75	1.46	5.3	0.12	0.48	0	0.87	0	0.54	0	0.63
103	0	0.72	0	2.37	0	0.6	0	0.53	0	0.33	0	0.36
104	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0.72	0	4.97	0	0.44	0	0.54	0	0.36	0	0.37
107	0.02	0.49	0.11	1.91	0.02	0.4	0.02	0.5	0.02	0.55	0.02	0.37
108	1.43	1.04	4.27	1.35	0.93	0.65	0.66	0.94	0.74	6.81	0.51	0.7
109	3.53	1.38	5.82	1.36	2.1	0.72	1.85	1.09	1.6	6.83	1.28	0.7
110	1.58	0.91	19.23	6.8	0.87	0.51	0.24	0.63	0.31	1.08	0.15	0.49
111	0.21	0.77	4.58	8.73	0.11	0.46	0.08	0.39	3.09	1.5	0.09	0.36
112	0.24	0.92	0.13	0.47	0.28	0.88	0.19	0.66	0.19	2.36	0.12	0.49
113	17.65	7.35	5.1	2.71	11.02	4.55	18.15	14.09	0.8	1.75	5.31	4.05
114	0.03	0.11	0.08	0.12	0.03	0.12	0	0	0	0	0	0
115	2.45	1.66	0.58	0.4	2.85	1.74	0.78	1.24	0.26	0.57	1.29	1.39
116	0.2	1.47	0.14	0.42	0.21	1.63	0.05	0.97	0.05	0.59	0.06	0.61
117	8.3	3.38	4.21	1.02	8.7	3.34	2.4	0.97	1.82	0.25	3.04	1.44
118	5.52	3.04	2.44	0.7	10.26	4.8	1.83	1.26	1.14	0.56	3.36	2.09
119	7.41	4.13	1.05	0.48	7.35	3.78	3.3	2.18	1.3	0.55	3.5	2.59
120	0.97	1.11	0.65	0.63	0.52	0.85	0.6	0.71	0.85	0.7	0.49	0.56
121	2.42	1.49	2.66	1.41	4.12	2.18	1.64	0.87	1.09	0.72	1.96	1.17
122	0.09	2.32	0.89	1.49	0.19	1.99	0.07	1.92	0.29	1.13	0.09	0.97
123	0.01	1.18	0.04	0.46	0	0.91	0.58	0.83	1.12	0.76	0.62	0.68
124	0.01	1.06	0.07	0.61	0.02	1.28	0.04	0.9	0.36	0.74	0.04	0.65
125	1.08	1.48	5.88	5.12	0.66	1.15	0.69	1.34	0.79	1.08	0.66	1.11
126	3.51	2.76	3.59	1.44	3.24	2.3	2.66	1.08	1.99	0.46	2.89	1.26
127	3.38	1.73	1.71	0.98	3.27	1.64	0.15	1.12	0.19	0.56	0.34	0.75
128	4.33	1.46	1.8	0.3	4.88	1.84	2.28	0.44	3.77	0.18	2.39	0.34
129	2.54	1.7	0.39	0.3	1.27	1.28	1.45	1.28	0.46	0.29	0.81	0.5
130	1.08	0.85	0.32	0.3	1.44	1.26	0.57	0.67	0.41	0.24	0.47	0.5

Table A1. Cont.

131	15.44	6.9	1.92	0.59	5.93	1.66	3.69	2.62	0.54	0.2	0.9	0.3
132	1.71	0.8	0.89	0.33	1.56	0.7	0.33	0.96	0.28	0.66	0.24	0.75
133	2.32	1.69	0.42	0.32	2.11	1.54	2.34	1.43	1	0.44	1.05	0.44
134	0.08	1.02	0.16	0.41	0.38	1.41	0.3	0.75	0.18	0.6	0.22	0.62
135	9.26	1.86	4.95	0.76	17.23	5.59	2.64	1.2	1.89	0.62	2.27	0.81
136	10.38	5.95	0.41	0.48	6.84	3.78	4.09	3.84	0.13	0.46	1.43	1.51
137	7.64	4.11	0.31	0.29	6.59	3.33	3.8	3.23	0.26	0.52	2.3	1.85
138	11.15	6.12	0.37	0.47	10.39	5.39	3.31	3.37	0.34	0.82	0.83	1.14
139	0.07	0.81	0.08	0.4	0.09	0.78	0.03	0.86	0.02	0.65	0.09	0.69
140	0.1	0.8	0.09	0.4	0.12	0.78	0.03	0.86	0.02	0.65	0.09	0.69
141	0.17	0.79	0.13	0.4	0.21	0.79	0.01	0.85	0.01	0.64	0.02	0.65
142	0.52	0.83	0.33	0.43	0.63	0.88	0	0.85	0	0.64	0.01	0.64
143	0.02	0.79	0.05	0.4	0.02	0.76	0.01	0.85	0.01	0.64	0.02	0.65
144	0.03	0.8	0.05	0.4	0.04	0.77	0.01	0.85	0.01	0.64	0.02	0.65
145	0.1	0.8	0.09	0.4	0.13	0.79	0.01	0.85	0.01	0.65	0.02	0.65
146	0.01	0.8	0.04	0.39	0.02	0.77	0	0	0	0	0	0
147	0	0.8	0.04	0.39	0	0.77	0	0	0	0	0	0
148	0.01	0.8	0.04	0.39	0.01	0.77	0	0	0	0	0	0
149	0.42	0.82	0.28	0.45	0.51	0.85	0.01	0.84	0.01	0.86	0.02	0.65
150	0	0.79	0.04	0.4	0	0.76	0	0.85	0	0.64	0	0.64
151	0.03	0.81	0.1	0.44	0.04	0.78	0.09	0.89	0.09	0.66	0.32	0.83
152	0.07	0.81	0.12	0.44	0.08	0.78	0.17	0.93	0.16	0.67	0.57	0.98
153	0.01	0.8	0.04	0.39	0.01	0.77	0.08	0.89	0.08	0.48	0.29	0.81
154	0.01	0.81	0.04	0.39	0.02	0.77	0.03	0.86	0.03	0.47	0.12	0.71
155	0	0.81	0.04	0.38	0	0.77	0.03	0.86	0.03	0.47	0.1	0.7
156	0.03	0.81	0.06	0.39	0.04	0.78	0.03	0.86	0.03	0.47	0.1	0.7
157	0	0.81	0.04	0.38	0	0.77	0.01	0.85	0.01	0.46	0.04	0.66
158	0.01	0.81	0.04	0.38	0.01	0.77	0.01	0.86	0.01	0.46	0.05	0.67
159	1.56	1.65	0.28	0.57	1.29	1.55	0.58	1.23	0.04	0.4	2.13	2.19
160	2.91	2.03	0.62	0.55	2.8	1.88	0.79	1.19	0.31	0.51	2.59	2.2
161	1.29	1.41	0.15	0.32	1.67	1.34	1.79	1.44	1.21	0.52	3.84	2.44
162	0.04	0.02	0.04	0.04	0.26	0.13	0.24	1.19	0.04	1.19	0.85	1.21
163	0	0	0.04	0.03	0	0	0	0	0	0	0	0

Sector ID	France						Germany					
	Final Demand		CO ₂		Employment		Final Demand		CO ₂		Employment	
	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd
1	0	0.03	0.04	0.06	0	0.03	0	0	0	0	0	0
2	0.27	0.66	1.02	1.3	0.7	0.89	0.15	0.73	0.03	0.44	0.22	0.88
3	0.21	0.39	0.99	1.06	0.36	0.47	0.14	0.71	0.1	0.53	0.25	0.89
4	1.15	0.89	1.14	1.12	1.71	1.04	0.28	0.61	0.04	0.41	0.54	0.8
5	0.11	0.41	0.52	0.75	0.3	0.5	0.06	0.57	0.01	0.37	0.28	0.75
6	0.05	0.47	0.18	0.56	0.16	0.52	0.03	0.7	0.01	0.42	0.08	0.86
7	0.01	0.03	0.04	0.05	0	0.03	0	0	0	0	0	0
8	0.23	0.24	0.32	0.32	0.24	0.26	0.15	1.06	0.05	0.72	0.4	1.21
9	0.27	1.07	0.44	1.26	0.13	1.13	0.12	1.44	0.01	1.12	0.25	2.04
10	0.12	1.08	0.1	1.17	0.09	1.18	0.3	1.11	0.06	0.9	0.22	1.49
11	0.24	1.16	0.09	1.2	0.08	1.18	0.14	0.56	0.01	0.5	0.12	0.59
12	0.12	0.17	0.08	0.18	0.06	0.17	0.04	0.08	0.02	0.05	0.03	0.08
13	0.01	0.05	0.04	0.08	0	0.05	0.02	0.06	0.01	0.03	0.02	0.05
14	0.41	0.99	0.37	1.01	0.81	1.23	0.39	0.62	0.07	0.42	0.34	0.78
15	0	0.54	0.04	0.49	0	0.57	0	0.62	0	0.48	0	1.01
16	0	0	0.09	0.07	0	0	0	0	0.01	0.01	0	0
17	0	0	0.04	0.03	0	0	0	0	0	0	0	0
18	0.36	0.44	0.26	0.45	0.3	0.46	0.14	0.44	0.05	0.24	0.2	0.56
19	0.09	0.38	0.27	0.73	0.13	0.46	0.02	0.43	0.02	1.02	0.02	0.41
20	0	1.47	0.08	0.85	0	2.38	0.14	1.5	4.39	1.92	0.21	1.33
21	0.02	0.68	0.07	0.42	0.01	0.83	0.02	0.67	0.05	0.6	0.01	0.93
22	0	0.63	0	0.4	0	0.82	0.11	0.69	0.06	0.61	0.02	0.9
23	0	0	0	0	0	0	0	0.48	0	0.38	0	0.99

24	0	0	0	0	0	0	0	0.83	0	0.78	0	1
25	0	0	0	0	0	0	0	0.88	0	0.81	0	0.96
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	1.54	0	1.33	0	1.42	0	0	0	0	0	0
29	0	0	0.02	0.02	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0.84	0.01	0.84	0	0.91
31	0	2.53	0	1.42	0	1.88	0	0.88	0	0.79	0	0.9
32	0.19	0.67	0.57	0.63	0.22	0.75	0.08	0.69	0.13	0.7	0.09	0.96
33	0.07	0.61	0.35	0.68	0.09	0.63	0.09	0.64	0.27	0.8	0.12	0.75
34	0.02	0.9	0.05	0.78	0.01	0.93	0.02	0.89	0.05	0.81	0.02	0.88
35	0.44	1.27	0.13	1.11	0.22	1.35	0.15	1.09	0.02	0.78	0.09	2.03
36	0.32	1.61	0.14	1.43	0.14	2.98	0.58	1.68	0.15	0.86	0.22	1.24
37	0.31	1.51	0.09	1.3	0.06	1.96	0.1	0.11	0.02	0.06	0.02	0.08
38	0.61	1.69	0.07	1.27	0.05	1.5	0.64	0.34	0.03	0.04	1.53	0.61
39	0.07	0.09	0.09	0.12	0.25	0.17	0.2	0.77	0.03	0.37	0.26	0.87
40	0.94	1.47	0.58	1.33	0.5	1.38	0.87	1.26	0.14	0.83	0.26	0.96
41	0.01	0.02	0.06	0.06	0.03	0.04	0	0.04	0	0.02	0.01	0.05
42	0.22	0.3	0.15	0.31	0.56	0.55	0.17	0.43	0.02	0.24	0.28	0.52
43	1.56	1.24	1.79	1.83	0.76	1.03	2.34	1.93	0.75	1.21	0.49	1.57
44	1.23	1.43	0.47	1.1	0.95	1.44	0.87	1.33	0.14	0.92	0.33	0.99
45	0.21	1.16	0.1	1.02	0.11	1.27	0.12	0.98	0.02	0.63	0.03	0.93
46	0.04	0.47	0.06	0.35	0.01	0.62	0.16	0.8	0.01	0.46	0.03	1.03
47	0.27	0.8	0.3	0.71	0.44	1.06	0.27	0.73	0.13	0.67	0.38	0.78
48	0.26	0.95	0.05	0.65	0.23	1.17	0.41	0.9	0.03	0.47	0.16	0.77
49	0	0.72	0.03	0.69	0.11	0.9	0.06	0.69	0.03	0.5	0.08	0.72
50	0.46	0.86	0.32	0.67	0.69	1.07	0.72	0.87	0.32	0.66	0.89	0.92
51	0.04	0.81	0.04	0.64	0.07	0.97	0.04	0.79	0.02	0.63	0.05	0.78
52	0.11	0.88	0.14	0.75	0.21	1.15	0.1	0.7	0.12	0.98	0.24	0.81
53	0.08	0.9	0.27	0.81	0.17	1.23	0.06	0.75	0.23	0.84	0.18	0.89
54	0.45	1.02	0.33	0.8	0.49	1.19	0.43	0.77	0.21	0.58	0.49	0.81
55	1.45	1.08	1.48	1.22	2.02	1.44	1.8	1.29	1.25	1.05	2.38	1.45
56	0.03	0.34	2.39	1.98	0.03	0.37	0.02	0.8	1.14	1.87	0.03	0.75
57	2.38	0.89	6.73	3.89	1.25	0.4	1.96	1.31	3.7	2.76	0.89	0.76
58	0	1.39	0.02	0.98	0.03	1.16	0	0.65	0	0.39	0	0.59
59	0.93	1.05	3.52	3.08	0.78	1.08	1.59	1.13	1.57	1.46	1.77	1.25
60	0.01	0.76	0.24	0.83	0.01	0.98	0.02	0.63	0.			

24	0	0	0	0	0	0	0	0.83	0	0.78	0	1
25	0	0	0	0	0	0	0	0.88	0	0.81	0	0.96
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	1.54	0	1.33	0	1.42	0	0	0	0	0	0
29	0	0	0.02	0.02	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0.84	0.01	0.84	0	0.91
31	0	2.53	0	1.42	0	1.88	0	0.88	0	0.79	0	0.9
32	0.19	0.67	0.57	0.63	0.22	0.75	0.08	0.69	0.13	0.7	0.09	0.96
33	0.07	0.61	0.35	0.68	0.09	0.63	0.09	0.64	0.27	0.8	0.12	0.75
34	0.02	0.9	0.05	0.78	0.01	0.93	0.02	0.89	0.05	0.81	0.02	0.88
35	0.44	1.27	0.13	1.11	0.22	1.35	0.15	1.09	0.02	0.78	0.09	2.03
36	0.32	1.61	0.14	1.43	0.14	2.98	0.58	1.68	0.15	0.86	0.22	1.24
37	0.31	1.51	0.09	1.3	0.06	1.96	0.1	0.11	0.02	0.06	0.02	0.08
38	0.61	1.69	0.07	1.27	0.05	1.5	0.64	0.34	0.03	0.04	1.53	0.61
39	0.07	0.09	0.09	0.12	0.25	0.17	0.2	0.77	0.03	0.37	0.26	0.87
40	0.94	1.47	0.58	1.33	0.5	1.38	0.87	1.26	0.14	0.83	0.26	0.96
41	0.01	0.02	0.06	0.06	0.03	0.04	0	0.04	0	0.02	0.01	0.05
42	0.22	0.3	0.15	0.31	0.56	0.55	0.17	0.43	0.02	0.24	0.28	0.52
43	1.56	1.24	1.79	1.83	0.76	1.03	2.34	1.93	0.75	1.21	0.49	1.57
44	1.23	1.43	0.47	1.1	0.95	1.44	0.87	1.33	0.14	0.92	0.33	0.99
45	0.21	1.16	0.1	1.02	0.11	1.27	0.12	0.98	0.02	0.63	0.03	0.93
46	0.04	0.47	0.06	0.35	0.01	0.62	0.16	0.8	0.01	0.46	0.03	1.03
47	0.27	0.8	0.3	0.71	0.44	1.06	0.27	0.73	0.13	0.67	0.38	0.78
48	0.26	0.95	0.05	0.65	0.23	1.17	0.41	0.9	0.03	0.47	0.16	0.77
49	0	0.72	0.03	0.69	0.11	0.9	0.06	0.69	0.03	0.5	0.08	0.72
50	0.46	0.86	0.32	0.67	0.69	1.07	0.72	0.87	0.32	0.66	0.89	0.92
51	0.04	0.81	0.04	0.64	0.07	0.97	0.04	0.79	0.02	0.63	0.05	0.78
52	0.11	0.88	0.14	0.75	0.21	1.15	0.1	0.7	0.12	0.98	0.24	0.81
53	0.08	0.9	0.27	0.81	0.17	1.23	0.06	0.75	0.23	0.84	0.18	0.89
54	0.45	1.02	0.33	0.8	0.49	1.19	0.43	0.77	0.21	0.58	0.49	0.81
55	1.45	1.08	1.48	1.22	2.02	1.44	1.8	1.29	1.25	1.05	2.38	1.45
56	0.03	0.34	2.39	1.98	0.03	0.37	0.02	0.8	1.14	1.87	0.03	0.75
57	2.38	0.89	6.73	3.89	1.25	0.4	1.96	1.31	3.7	2.76	0.89	0.76
58	0	1.39	0.02	0.98	0.03	1.16	0	0.65	0	0.39	0	0.59
59	0.93	1.05	3.52	3.08	0.78	1.08	1.59	1.13	1.57	1.46	1.77	1.25
60	0.01	0.76	0.24	0.83	0.01	0.98	0.02	0.63	0.02	0.47	0.02	0.87
61	0	0.75	1.13	1.45	0	1.01	0	0.63	0.67	1.1	0	0.86
62	0.01	0.75	0.05	0.62	0.01	1.01	0.02	0.63	0.15	0.65	0.04	0.85
63	1.18	1.57	1.83	1.92	0.42	1.33	0.37	1.19	0.49	0.98	0.24	1.14
64	1.05	1.04	1.19	1.39	1.54	1.42	1.21	0.99	0.89	1.02	1.91	1.39
65	0.08	0.79	0.95	1.32	0.12	1	0.2	0.79	0.73	1.08	0.28	0.93
66	0.04	0.77	0.3	0.79	0.07	1.01	0.05	0.8	0.23	0.75	0.09	0.97
67	0.09	0.76	0.22	0.82	0.12	0.87	0.12	0.64	0.07	0.54	0.13	0.67
68	0.09	0.75	0.61	1.1	0.1	0.9	0.08	0.7	0.27	0.78	0.09	0.8
69	0.83	0.85	7.36	6.15	0.85	1.2	0.66	0.83	3.68	3.84	0.68	1.07
70	0.01	0.85	0.59	2.25	0.01	1.12	0.03	0.8	0.41	1.41	0.03	1
71	0.13	0.77	0.7	1.01	0.14	0.92	0.22	0.77	0.42	0.96	0.21	0.87
72	0.31	0.79	9.67	7.65	0.53	1.07	0.45	0.5	9.07	8.21	0.91	0.75
73	0.07	0.74	2.44	2.83	0.13	0.96	0.12	0.56	2.2	3.33	0.24	0.7
74	0.01	0.96	0.03	0.58	0.01	1	0.01	0.46	0.02	0.4	0.02	0.5
75	0	0	0	0	0	0	0	0	0	0	0	0
76	0.08	0.92	0.48	1.02	0.1	1.21	0.11	0.58	0.48	1.28	0.17	0.72
77	0.01	0.89	0.02	0.7	0.01	1.25	0.02	0.6	0.04	0.5	0.03	0.77
78	0	0.54	0.04	0.43	0	0.67	0.01	0.41	0.08	0.41	0.02	0.49
79	0	0.45	0.04	0.36	0	0.58	0	0.39	0.02	0.34	0.01	0.47
80	0.08	0.67	0.16	0.48	0.13	0.73	0.06	0.42	0.12	0.48	0.15	0.47
81	0	0	0	0	0	0	0.01	0.42	0.02	0.52	0.02	0.45
82	0	1.24	0.01	0.73	0	1.03	0.02	0.73	0.04	0.59	0.03	0.6
83	0	0	0	0	0	0	0	0	0	0	0	0

Table A1. Cont.

84	0.27	0.86	1.21	1.36	0.29	1.06	0.34	0.54	1.04	1.09	0.42	0.64
85	2.56	1.09	2.52	1.24	3.41	1.54	2.91	1.14	2	1.15	4.21	1.58
86	1.75	1.33	0.98	1	1.92	1.54	4.34	2.35	2.5	1.1	4.3	2.08
87	0	0.74	0.01	0.52	0.03	0.9	0.32	0.83	0.11	0.46	0.24	0.8
88	0.69	0.95	0.7	1.02	0.94	1.19	1.99	1.13	2.22	0.79	2.45	1.46
89	0.46	1.03	0.21	0.73	0.55	1.2	1.22	1.16	0.2	0.5	0.76	1.11
90	0.56	0.9	0.35	0.76	0.78	1.16	1.17	1.1	0.3	0.5	1.19	1.15
91	2.93	2.08	0.64	1.2	1.22	1.38	5.98	3.5	1.19	1.06	3.58	1.9
92	1.02	1.06	1.34	0.9	0.98	1.15	0.75	1.01	0.52	0.76	0.58	1.07
93	0.7	1.12	0.23	0.8	0.69	1.31	1.06	1.26	0.13	0.6	0.81	1.13
94	0.07	0.64	0.68	1.26	0.12	0.83	0.15	1.16	0.48	0.75	0.25	1.19
95	0.07	0.64	0.68	1.26	0.12	0.83	0	0	0	0	0	0
96	0.11	0.47	7.69	6.07	0.06	0.45	0.57	0.96	31.48	28.96	0.42	0.86
97	0.36	0.21	5.36	4.07	0.25	0.19	0.23	0.63	5.49	5.13	0.13	0.53
98	0.96	0.94	0.72	0.4	0.63	0.74	0.24	0.7	0.2	0.29	0.18	0.68
99	0.12	1.18	0.09	0.59	0.07	0.94	0.04	0.76	0.03	0.33	0.03	0.73
100	0.01	1.21	0.01	0.61	0	0.98	0.07	0.78	0.05	0.33	0.05	0.75
101	0.09	0.24	2.14	1.79	0.06	0.26	0.02	0.66	0.68	0.93	0.01	0.62
102	0.06	0.39	0.77	0.87	0.04	0.41	0.05	0.97	0.76	1.08	0.04	0.94
103	0	1.29	0	0.63	0	1.04	0.01	0.78	0	0.34	0	0.76
104	0	0	0	0	0	0	0	0	0	0	0	0
105	0.01	0.3	0	0.24	0	0.33	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0
107	0.02	0.22	0.01	0.17	0.01	0.23	0.02	0.67	0.02	0.28	0.01	0.64
108	0.2	1.03	0.14	1.17	0.1	0.76	0.46	0.85	0.3	1.31	0.27	0.69
109	0.62	1.18	0.22	1.21	0.27	0.79	1.75	1.21	0.65	1.33	0.88	0.73
110	0.94	0.71	4.83	0.5	0.66	0.81	1.07	1.68	6.33	0.48	0.52	1.25
111	0.01	0.31	4.01	3.3	0.01	0.35	0.04	1.08	4.45	4.46	0.02	0.88
112	0.51	1.58	0.42	1.02	0.41	1.54	0.39	0.64	0.29	0.55	0.28	0.54
113	15.01	7.03	2.91	2.37	9.13	3.66	11.03	5.7	1.6	0.85	7.23	2.98
114	0.01	0.08	0.06	0.1	0.01	0.1	0.02	0.1	0	0.07	0.03	0.1
115	2	1.41	0.64	0.78	2.22	1.3	2.07	1.58	0.75	0.47	3.02	1.38
116	0.19	1.27	0.34	0.78	0.17	1.52	0.13	1.97	0.13	0.37	0.15	1.21
117	7.69	3.21	6.61	2.68	7.51	2.66	6.02	2.85	2.96	1.24	5.92	2.16
118	5.26	2.47	3.37	1.32	9.03	3.35	5.69	3.21	2.42	1.11	10.26	3.97
119	4.8	2.67	1.32	0.96	5.09	2.21	3.39	2.52	0.37	0.47	5	2.34
120	1.19	0.99	0.62	0.95	0.93	0.88	0.75	0.89	1.05	0.84	0.84	0.91
121	2.2	1.21	2.45	1.99	3.04	1.35	1.6	0.98	2.93	1.11	3.22	1.47
122	0.08	1.53	0.23	1.12	0.09	1.67	0.02	1.51	0.07	0.71	0.06	1.55
123	0.1	1.06	3.41	3.46	0.13	1.37	0.17	0.62	12.51	11.76	0.17	0.7
124	0.02	1.29	0.33	1.43	0.01	2.11	0.06	0.65	0.14	0.92	0.02	0.77
125	0.51	0.93	7.35	6.31	0.52	1	0.93	0.88	4.62	4.59	0.54	0.69
126	2.29	0.94	4.87	1.98	3.58	1.45	2.84	1.12	9.46	1.75	4.1	1.42
127	3.45	1.54	3.13	1.84	4.16	1.55	3.67	2.01	1.58	0.89	3.19	1.22
128	4.77	1.62	2.7	0.7	5.54	1.7	5.14	1.92	1.76	0.38	4.61	1.72
129	2.52	1.85	0.92	0.73	1.38	1.55	3.42	2.49	0.97	0.6	1.57	2.25
130	1.76	1.04	1.39	0.75	2.21	1.61	1.32	0.71	0.47	0.21	1.74	0.94
131	17.34	7.24	2.4	0.46	4.21	0.75	16.51	6.71	2.82	0.21	6.02	0.89
132	1.31	0.8	1.65	0.8	1.51	1.1	1.97	0.3	3	0.25	2.07	0.35
133	3.65	1.61	1.8	0.68	3.87	1.41	1.9	0.89	0.69	0.21	2.45	0.92
134	1.38	1.31	1.43	0.88	1.66	1.47	0.6	1.3	0.23	0.45	0.56	1.26
135	14.25	2.1	12.89	1.94	24.92	5.29	11.09	1.51	8.84	1.14	21.65	5.28
136	10.56	5.29	1.51	0.83	9.67	3.74	9.95	5.32	2.53	0.89	7.61	3.09
137	6.43	3.09	0.87	0.43	8.05	2.92	6.77	3.48	0.75	0.57	7.21	2.69
138	11.65	5.75	0.58	0.53	12.82	4.73	12.32	6.71	0.51	0.65	11.21	4.5
139	0.08	0.77	0.24	0.38	0.08	0.67	0.13	0.92	0.06	0.44	0.1	1.26
140	0.08	0.77	0.24	0.38	0.08	0.68	0.18	0.92	0.09	0.44	0.14	1.26
141	0.03	0.76	0.18	0.37	0.04	0.67	0.18	0.9	0.08	0.43	0.14	1.26
142	0.1	0.78	0.28	0.39	0.1	0.68	0.22	0.95	0.11	0.45	0.17	1.27
143	0.02	0.76	0.16	0.38	0.02	0.67	0.03	0.88	0.01	0.44	0.02	1.25

Table A1. Cont.

144	0.02	0.76	0.17	0.38	0.02	0.67	0.11	0.9	0.05	0.44	0.09	1.25
145	0.09	0.77	0.26	0.38	0.1	0.68	0.18	0.92	0.08	0.44	0.13	1.26
146	0.01	0.76	0.15	0.36	0.01	0.67	0.03	0.88	0.02	0.43	0.03	1.25
147	0	0.76	0.14	0.36	0	0.67	0	0.88	0	0.43	0	1.25
148	0.08	0.77	0.24	0.37	0.08	0.68	0.18	0.92	0.08	0.43	0.14	1.27
149	0.05	0.77	0.2	0.41	0.05	0.67	0.1	0.91	0.05	0.46	0.07	1.25
150	0	0.76	0.14	0.37	0	0.67	0	0.87	0	0.43	0	1.25
151	0.03	0.76	0.21	0.43	0.03	0.67	0.04	0.91	0.05	0.48	0.03	1.25
152	0.05	0.77	0.24	0.43	0.05	0.67	0.09	0.92	0.07	0.48	0.07	1.25
153	0.05	0.77	0.2	0.38	0.05	0.67	0	0.9	0	0.44	0	1.25
154	0.03	0.77	0.18	0.38	0.03	0.67	0	0.9	0	0.44	0	1.25
155	0.01	0.76	0.15	0.37	0.01	0.67	0	0.9	0	0.43	0	1.25
156	0.14	0.78	0.32	0.39	0.14	0.68	0.04	0.91	0.02	0.44	0.03	1.25
157	0.01	0.76	0.14	0.37	0.01	0.67	0	0.89	0	0.43	0	1.25
158	0.02	0.76	0.16	0.37	0.02	0.67	0	0.89	0	0.43	0	1.25
159	0.52	1.24	0.42	0.8	0.7	1.24	1.17	0.94	0.44	0.29	1.74	0.91
160	4.14	2.62	1.47	1.32	3.56	1.94	3.46	1.94	0.93	0.63	3.67	1.46
161	0.87	0.9	0.33	0.54	0.96	0.89	1.99	1	0.58	0.32	2.64	0.95
162	0.59	0.25	0.28	0.21	1.92	0.66	0.4	0.2	0.02	0.01	1.84	0.67
163	0	0	0.13	0.1	0	0	0	0	0	0	0	0

Sector ID	Sweden						USA					
	Final Demand		CO ₂		Employment		Final Demand		CO ₂		Employment	
	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd	Fwd	Bckwd
1	0	0	0	0	0	0	0.02	1.61	0.02	0.64	0.04	0.67
2	0.14	0.78	0.33	0.76	0.22	0.76	0.05	1.87	0.09	0.7	0.06	0.77
3	0.2	0.71	0.39	0.73	0.46	0.76	0.17	1.59	0.44	0.81	0.17	0.71
4	0.08	0.51	0.17	0.37	0.1	0.49	0.4	0.99	0.15	0.61	0.47	0.66
5	0.04	0.2	0.09	0.18	0.11	0.22	0.07	1.53	0.13	0.64	0.09	0.65
6	0.02	0.73	0.04	0.4	0.02	0.71	0.02	1.43	0.02	0.74	0.02	0.73
7	0	0	0	0	0	0	0.02	1.47	0.04	0.78	0.04	0.76
8	0.09	1.08	0.13	0.6	0.27	1.05	0.3	1.21	0.3	0.78	0.71	0.9
9	0.08	1.82	0.13	1.25	0.18	1.91	0.37	1.45	0.19	0.82	0.27	0.89
10	0.22	0.77	0.08	0.49	0.24	0.83	0.1	0.88	0.05	0.5	0.14	0.55
11	0.12	0.63	0.02	0.42	0.11	0.64	0.19	1.39	0.07	1.06	0.15	1.16
12	0.07	0.26	0.04	0.16	0.08	0.28	0	0.77	0	0.44	0	0.58
13	0.06	0.28	0.03	0.17	0.07	0.3	0.05	0.87	0	0.64	0.02	0.75
14	0.39	0.6	0.19	0.37	0.45	0.73	0.18	1.08	0.06	0.76	0.22	0.78
15	0	0.69	0	0.4	0	0.71	0	0.87	0	0.54	0	0.68
16	0	0	0.01	0.01	0	0	0	0	0.04	0.02	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0.71	0.32	0.84	0.49	1.28	0.52	0.26	0.74	0.53	0.65	0.57	0.75
19	0.05	0.47	0.07	0.5	0.06	0.5	0.01	0.68	0.02	0.46	0.03	0.68
20	0.03	0.61	0.42	0.58	0.04	0.71	0.17	0.56	8.1	0.74	0.2	0.84
21	0	0	0	0	0	0	0.47	0.81	1.42	0.87	0.32	1.01
22	0	0	0	0	0	0	0.63	0.73	4.95	1.44	0.5	0.94
23	0	0	0	0	0	0	0.06	0.79	0.01	1.35	0	0.81
24	0	0	0	0	0	0	0	0.38	0	0.94	0.01	0.61
25	0	0.46	0.65	0.87	0.01	0.48	0.04	0.79	0.26	1.25	0.04	1.31
26	0.13	0.37	0.31	0.36	0.16	0.43	0.02	0.48	0.04	1.03	0.02	0.62
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0.46	0	0.91	0	0.7
29	0	0.47	0.41	0.71	0	0.49	0.01	0.51	0.02	0.99	0.02	0.71
30	0.01	0.51	0.14	0.49	0.03	0.53	0	0.66	0	1.37	0	0.69
31	0	0.4	0	0.36	0	0.39	0	0.57	0	0.95	0	0.75
32	0.15	0.62	0.11	0.54	0.14	0.72	0.09	0.55	0.25	0.81	0.1	0.82
33	0.12	0.48	0.15	0.46	0.12	0.52	0.06	0.57	0.13	0.91	0.07	0.87
34	0.02	0.8	0.05	0.6	0.01	0.77	0.02	0.62	0.14	1.05	0.03	0.86
35	0.51	0.86	0.09	0.53	0.2	0.85	0.3	1.49	0.07	0.87	0.11	0.99
36	0.53	0.92	0.19	0.59	0.23	0.9	0.24	1.08	0.11	0.88	0.16	1.13

Table A1. Cont.

37	0.14	1.14	0.05	1.03	0.04	2.34	0.33	1.21	0.13	1.15	0.23	1.42
38	0.37	0.74	0.03	0.36	0.08	0.67	0.15	1	0.04	1.08	0.24	1.38
39	0.01	0.06	0	0.05	0.02	0.09	0.15	1.4	0.09	0.89	0.11	1.04
40	0.91	1.36	0.42	0.89	0.28	1.09	0.56	1.18	0.12	0.97	0.4	1.16
41	0	0.9	0	1.14	0	1.3	0	1.31	0	1.36	0	1.83
42	0.04	0.46	0.02	0.28	0.01	0.48	0.06	1.13	0.04	0.99	0.04	1.15
43	1.1	1.1	0.5	0.93	1.13	1.08	2.03	1.63	1.18	1.51	1.24	1.41
44	0.44	1.27	0.12	0.81	0.23	1.24	0.57	1.19	0.08	1.06	0.15	1.27
45	0.04	1.16	0.01	0.73	0.02	1.18	0.07	0.72	0.02	0.71	0.09	0.97
46	0	0	0	0	0	0	0.36	0.48	0.02	0.35	0.02	0.44
47	0.06	0.65	0.11	0.56	0.21	0.78	0.67	1.04	0.35	1.1	0.54	1.17
48	0.01	0.82	0.01	0.62	0.06	0.9	0.24	0.95	0.03	0.9	0.14	1.37
49	0	0.74	0.01	0.47	0.03	0.84	0.04	0.83	0.01	0.82	0.03	1.13
50	1.94	0.85	1.58	0.93	2.26	1.21	0.76	0.84	0.53	0.88	0.93	1.07
51	0.01	0.76	0	0.79	0.01	0.86	0	0.75	0.03	0.79	0	0.97
52	0.1	0.77	0.5	1.16	0.22	0.89	0.01	0.85	0.06	0.97	0.02	0.98
53	0.01	0.89	0.82	1.65	0.03	0.96	0	0.74	0.11	0.92	0.01	0.94
54	0.81	0.85	0.93	0.94	1.38	1.11	1.19	0.84	1.14	1.07	1.24	1.02
55	2.14	1.41	2.43	1.91	2.82	1.55	2.06	0.99	1.82	1.16	2.64	1.29
56	0.03	0.4	2.16	2.33	0.03	0.57	0	1.12	0.1	1.12	0	1.18
57	1.06	0.31	4.94	2.81	0.56	0.03	1.81	0.97	5.23	2.84	0.86	0.76
58	0	0.67	0.02	0.51	0.08	0.72	0	1.03	0	1.16	0	0.68
59	0.97	0.73	1.62	1.32	1.42	1.03	0.31	0.99	0.37	1.51	0.31	1.3
60	0	0.77	0.03	0.52	0.01	0.98	0.04	0.97	0.03	1.39	0.04	1.31
61	0	0.25	7.9	6.73	0	0.23	0	0.99	1.32	1.99	0	1.29
62	0	0.5	0.02	0.39	0	0.66	0.06	1.01	0.64	1.44	0.09	1.27
63	0.01	0.85	0.09	0.63	0.01	0.93	2.84	1.21	3.17	2.05	2.07	1.31
64	0.54	0.73	0.51	0.74	0.94	1.02	1.33	0.85	1.15	1.19	1.47	1.15
65	0.05	0.71	0.45	0.94	0.06	0.76	0.16	0.69	0.51	1.1	0.18	0.92
66	0.03	0.7	0.19	0.71	0.03	0.75	0.01	0.58	0.21	0.87	0.01	0.87
67	0.09	0.74	0.12	0.74	0.09	0.76	0.03	0.61	0.03	0.8	0.03	0.92
68	0.01	0.67	0.07	0.72	0.01	0.7	0.04	0.61	0.23	0.89	0.05	0.85
69	0.77	0.84	6	5.54	0.79	1	0.43	0.73	1.79	1.73	0.51	1.03
70	0	0.81	0.4	1.75	0	0.87	0.01	0.71	0.16	0.94	0.01	0.98
71	0.06	0.66	0.26	0.8	0.07	0.69	0.11	0.66	0.29	0.89	0.13	0.91
72	0.23	0.59	14.69	12.41	0.69	0.83	0.44	0.94	2.42	2.17	0.58	1.17
73	0.08	0.56	4.55	4.47	0.25	0.68	0.01	0.84	0.13	1.51	0.01	1.07
74	0.02	0.66	0.07	0.44	0.02	0.7	0.04	0.71	0.03	0.83	0.04	0.93
75	0	0	0	0	0	0	0	0.71	0	0.73	0	0.94
76	0.16	0.57	1.55	1.57	0.18	0.66	0.16	0.82	0.51	1.34	0.17	0.92
77	0.01	0.59	0.05	0.59	0.01	0.69	0.04	0.83	0.07	0.79	0.05	0.94
78	0.04	0.62	0.34	0.69	0.05	0.71	0	0.39	0.01	0.53	0	0.51
79	0	0.59	0.03	0.51	0	0.68	0	0.34	0	0.41	0	0.47
80	0.48	0.8	0.81	0.81	0.49	0.87	0.08	0.75	0.06	0.72	0.09	0.88
81	0.02	0.75	0.08	0.69	0.02	0.82	0	0.75	0	0.79	0.01	0.88
82	0.01	0.65	0.01	0.43	0.01	0.66	0.01	0.9	0.01	1.17	0.01	0.95
83	0	1.75	0	1.06	0	1.83	0.01	0.9	0.01	0.85	0.01	0.96
84	0.15	0.71	1.22	1.54	0.17	0.78	0.2	0.73	0.29	0.98	0.21	1
85	2.45	1.13	1.89	1.07	3.53	1.65	1.88	0.8	1.56	0.98	2.36	1.26
86	3.27	1.94	1.7	1.13	3.55	2.05	2.34	1.28	1.62	0.89	1.71	1.16
87	−0.01	0.65	0.02	0.47	0.09	0.78	0.51	0.92	0.07	0.67	0.14	1.08
88	1.32	1.11	0.64	0.67	1.28	1.28	0.6	0.68	0.41	0.78	0.62	0.96
89	0.55	0.88	0.29	0.53	0.94	1.3	1.38	0.9	0.53	0.72	1.12	1.15
90	0.89	0.93	0.23	0.51	0.93	0.99	1.13	1.01	0.2	0.75	0.67	1.15
91	3.96	2.39	1.26	1.14	2.94	1.82	3.61	1.9	0.95	0.94	1.53	1.16
92	0.71	0.76	0.99	0.57	0.92	0.93	1	0.91	0.37	0.78	0.7	1.18
93	0.77	0.98	0.4	0.84	1.22	1.25	1.21	1.12	0.33	0.82	1.11	1.2
94	0.08	0.75	1.48	1.46	0.17	0.85	0	0.63	0	0.76	0	0.87
95	0	0	0.01	0.01	0	0	0	0	0	0	0	0
96	0.06	0.62	1.03	1.28	0.02	0.64	0.55	0.72	35.63	20.92	0.47	0.82

Table A1. Cont.

97	0.03	0.56	2.54	2.46	0.01	0.55	0.23	0.67	7.06	4.81	0.17	0.79
98	0.55	0.59	1.21	0.23	0.41	0.55	0.19	0.31	0.13	0.21	0.17	0.37
99	0.53	0.73	1.24	0.28	0.36	0.63	0.05	0.39	0.04	0.25	0.05	0.42
100	0.01	0.61	0.02	0.29	0.01	0.6	0.01	0.4	0.01	0.26	0.01	0.43
101	0.03	0.54	0.87	1.22	0.01	0.52	0.02	0.61	1.06	1.34	0.02	0.72
102	0.45	0.75	1.04	1.06	0.19	0.63	0.01	0.55	0.3	0.56	0.01	0.69
103	0	0.53	0	0.26	0	0.58	0	0.49	0	0.29	0	0.54
104	0	0	0	0	0	0	0	0.45	0	0.27	0	0.5
105	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0.46	0	0.27	0	0.51
107	0.02	0.57	0.01	0.36	0.01	0.55	0	0.48	0	0.36	0	0.54
108	0.35	0.68	0.92	0.37	0.22	0.6	0.14	0.46	0.1	0.29	0.11	0.49
109	1.1	0.96	1.04	0.37	0.59	0.7	0.64	0.58	0.31	0.3	0.46	0.51
110	0.03	0.7	0.23	0.49	0.02	0.69	0.69	0.73	0.93	0.92	0.48	0.75
111	0.44	0.78	10.25	8.84	0.18	0.65	0	0.66	0.69	0.91	0	0.67
112	0.48	0.94	0.19	0.48	0.39	0.9	0.03	0.93	0.01	0.46	0.01	0.82
113	13.69	5.69	2.49	1.32	8.7	3.79	9.62	4.25	2.91	1.34	7.13	2.87
114	0.01	0.1	0	0.09	0.01	0.15	0	0.1	0	0.17	0	0.13
115	1.54	1.32	0.85	0.69	2.2	1.37	3.48	1.75	0.68	0.5	4.29	1.72
116	0.23	1.76	0.3	0.72	0.21	1.33	0.12	0.99	0.11	0.9	0.1	1.44
117	6.55	2.93	3.96	1.55	8.49	3.45	6.42	2.24	5.61	1.04	8.93	2.87
118	4.28	2.61	2.01	1.08	5.97	2.78	4.58	2.12	5.21	1.38	6.07	2.17
119	3.61	2.85	0.85	0.55	4.18	2.19	5.24	2.59	1.85	0.92	8.86	3.25
120	0.87	0.8	0.77	0.58	0.68	0.67	0.35	0.83	0.98	0.95	0.3	0.83
121	3.36	1.15	5.34	2.03	5.26	1.9	2.03	1.23	2.68	1.57	2.22	1.3
122	0.1	1.27	0.37	0.99	0.14	1.33	0.2	1.13	1.03	1.53	0.13	1.39
123	0.28	0.86	8.92	7.92	0.53	0.99	0.02	1.23	0.49	1.03	0.05	0.98
124	0.04	0.91	0.72	1.56	0.03	0.97	0.03	0.93	0.2	1.01	0.01	1.28
125	0.66	1.06	11.69	10.23	0.54	0.94	0.71	1.03	4.39	3.14	0.55	0.88
126	4.92	2.12	9.83	2.89	4.75	1.74	1.02	0.83	2	0.88	2.21	1.19
127	3.94	2.04	2.6	1.53	3.79	1.74	4.78	1.54	4.07	1.64	4.71	1.22
128	3	1.6	0.99	0.42	2.44	1.33	5.4	1.66	2.38	0.49	5.07	1.4
129	2.11	1.63	0.59	0.3	1.01	0.91	3.91	1.48	1.03	0.4	3.25	1.11
130	0.31	1.4	0.3	0.47	0.54	1.12	3.71	1.17	2.01	0.3	3.2	0.9
131	18.29	7.52	2.9	0.89	8.04	1.7	16.42	5.9	3.19	0.54	6.75	0.83
132	0.84	1	1.18	0.6	0.71	0.95	1.8	0.75	3.04	0.95	1.89	0.78
133	3.81	2.04	1.79	0.6	4.18	2	3.88	1.61	1.4	0.6	2.99	1.14
134	0.34	1.23	0.55	0.72	1.99	1.87	0.9	0.78	0.7	0.66	1.44	1.22
135	9.94	1.7	8.31	1.71	16.59	4.42	13.65	1.11	14.64	2.47	24.04	4.2
136	10.14	5.58	1.32	0.72	7.79	3.62	18.86	8.58	4.5	2.71	9.5	3.49
137	9.35	5.7	0.38	0.42	10.74	5.18	1.31	1.69	0.13	0.62	8.56	3.41
138	17.65	9.53	0.52	0.47	17.47	8.06	10.59	5.47	0.49	0.8	10.59	4.13
139	0.07	0.94	0.08	0.65	0.06	1.12	0.01	0.7	0.01	0.58	0.02	0.8
140	0.06	0.93	0.07	0.64	0.06	1.13	0.02	0.7	0.01	0.57	0.03	0.8
141	0.04	0.92	0.04	0.63	0.04	1.17	0.05	0.69	0.02	0.56	0.05	0.8
142	0.32	0.9	0.23	0.65	0.34	1.24	0.02	0.7	0.02	0.57	0.02	0.8
143	0.01	0.93	0.02	0.64	0.01	1.13	0.01	0.7	0	0.57	0.01	0.8
144	0.06	0.93	0.06	0.64	0.05	1.14	0.01	0.7	0	0.57	0.01	0.8
145	0.06	0.94	0.07	0.64	0.06	1.13	0	0.7	0	0.57	0	0.8
146	0	0.97	0.01	0.63	0	1.21	0	0	0	0	0	0
147	0	0.98	0.01	0.62	0	1.22	0	0	0	0	0	0
148	0.03	0.98	0.03	0.61	0.03	1.24	0.13	0.75	0.07	0.55	0.15	0.83
149	0.03	0.91	0.05	0.66	0.04	1.14	0	0.7	0	0.62	0	0.8
150	0	0	0.01	0.01	0	0	0.04	0.7	0.02	0.56	0.05	0.8
151	0.01	0.91	0.06	0.68	0.01	1.13	0.03	0.69	0.03	0.57	0.03	0.89
152	0.02	0.91	0.07	0.69	0.02	1.13	0.01	0.68	0.02	0.63	0.01	0.99
153	0	0.93	0.01	0.64	0	1.16	0.03	0.7	0.02	0.55	0.04	0.8
154	0.01	0.94	0.02	0.63	0.01	1.18	0.04	0.7	0.02	0.55	0.05	0.81
155	0	0.94	0.01	0.63	0	1.18	0.03	0.7	0.02	0.54	0.04	0.8
156	0.03	0.94	0.03	0.64	0.03	1.19	0.05	0.7	0.03	0.54	0.06	0.81

Table A1. Cont.

157	0	0.94	0.01	0.63	0	1.18	0.01	0.7	0.01	0.54	0.01	0.8
158	0	0.94	0.01	0.63	0	1.19	0.01	0.7	0.01	0.54	0.02	0.8
159	2.68	2.02	0.72	0.85	2.94	1.98	1.42	1.81	0.51	0.79	2.69	1.81
160	3.89	2.89	1.32	1.1	3.68	2.17	2.81	1.5	1.53	0.97	3.26	1.48
161	0.98	1.33	0.23	0.43	1.13	1.02	1.14	1.14	0.3	0.66	1.59	1.19
162	0.04	0.02	0.01	0.01	0.05	0.02	0.12	0.05	0.01	0	0.51	0.16
163	0	0	0.01	0.01	0	0	0	0	0	0	0	0

Appendix B. Complete Forward and Backward Linkage Charts

Figure A1. Final demand-weighted forward and backward linkage coefficient comparison for the six countries (sector ID index can be found in Appendix D: Multi-criteria decision analysis results summary).

Figure A2. CO₂ emissions-weighted forward and backward linkage coefficient comparison for the six countries (sector ID index can be found in Appendix D: Multi-criteria decision analysis results summary).

Figure A3. Employment-weighted forward and backward linkage coefficient comparison for the six countries (sector ID index can be found in Appendix D: Multicriteria decision analysis results summary).

Appendix C. Linkage Coefficient Trade-Off Charts

Figures A4–A7 show the trade-offs between linkage coefficients for final demand, CO₂ emissions, and employment for each of the six countries observed in this study. This is intended as an alternative way to visualize the EE I-O key sector analysis results. The average of the forward and backwards coefficients was used for each data point. The average CO₂ linkages and final demand linkages are shown on each x- and y-axis, respectively, and the size of the circles encodes the average employment linkage. The most sustainable sectors tend to coalesce at the top-left quadrant of each graph, and are those with relatively high average employment linkage coefficients.

Figure A4. Trade-off of average forward and backward linkage coefficients (Austria).

Figure A5. Trade-off of average forward and backward linkage coefficients (China).

Figure A6. Trade-off of average forward and backward linkage coefficients (Germany).

Figure A7. Trade-off of average forward and backward linkage coefficients (Sweden).

Appendix D. Multi-Criteria Decision Analysis Results Summary

Table A2. Complete sector sustainability rankings for all six countries, by number of other sectors outranked.

Sector ID	Sector Name	Overall Sustainability Ranking, by Country					
		Austria	China	France	Germany	Sweden	USA
1	Cultivation of paddy rice	138	74	153	144	141	37
2	Cultivation of wheat	39	29	118	66	118	31
3	Cultivation of cereal grains nec	92	25	141	68	97	111
4	Cultivation of vegetables, fruit, nuts	68	4	81	59	126	27
5	Cultivation of oil seeds	101	28	139	86	108	39
6	Cultivation of sugar cane, sugar beet	87	26	120	79	57	59
7	Cultivation of plant-based fibers	138	58	153	144	141	62
8	Cultivation of crops nec	14	7	141	22	17	23
9	Cattle farming	7	23	104	16	14	15
10	Pigs farming	19	8	54	25	22	64
11	Poultry farming	31	13	42	113	75	34
12	Meat animals nec	138	15	100	131	97	88
13	Animal products nec	138	17	153	144	97	55
14	Raw milk	15	31	44	54	47	48
15	Wool, silk-worm cocoons	95	51	91	81	62	54
16	Manure treatment (conventional), storage and land application	138	146	153	144	141	153
17	Manure treatment (biogas), storage and land application	138	146	153	144	141	153
18	Forestry, logging and related service activities	97	17	99	116	112	102
19	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing	31	3	127	138	104	95
20	Mining of coal and lignite; extraction of peat	53	93	4	123	123	152
21	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	105	106	50	90	141	108
22	Extraction of natural gas and services related to natural gas extraction, excluding surveying	132	140	48	86	141	134
23	Extraction, liquefaction, and regasification of other petroleum and gaseous materials	138	146	127	89	141	111
24	Mining of uranium and thorium ores	138	136	127	72	141	150
25	Mining of iron ores	31	113	127	75	135	64
26	Mining of copper ores and concentrates	138	128	127	144	134	149
27	Mining of nickel ores and concentrates	138	136	127	144	141	153
28	Mining of aluminium ores and concentrates	138	130	22	144	141	147
29	Mining of precious metal ores and concentrates	138	130	153	144	132	135
30	Mining of lead, zinc and tin ores and concentrates	138	99	127	92	102	147
31	Mining of other non-ferrous metal ores and concentrates	91	107	10	81	104	127
32	Quarrying of stone	35	118	121	90	86	123
33	Quarrying of sand and clay	95	102	125	113	119	114
34	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	39	73	57	83	74	110
35	Processing of meat cattle	21	32	23	19	15	20
36	Processing of meat pigs	8	21	3	15	51	34
37	Processing of meat poultry	107	27	8	131	5	20
38	Production of meat products nec	30	44	6	64	21	38
39	Processing vegetable oils and fats	77	50	111	61	141	32
40	Processing of dairy products	26	40	54	48	64	14
41	Processed rice	138	136	153	144	47	15
42	Sugar refining	102	36	73	108	92	40
43	Processing of Food products nec	77	5	98	74	52	88
44	Manufacture of beverages	18	33	29	45	13	10

Table A2. Cont.

Sector ID	Sector Name	Overall Sustainability Ranking, by Country					
		Austria	China	France	Germany	Sweden	USA
45	Manufacture of fish products	27	6	32	58	20	71
46	Manufacture of tobacco products	81	55	67	63	141	96
47	Manufacture of textiles	81	46	50	62	62	23
48	Manufacture of wearing apparel; dressing and dyeing of fur	27	24	9	51	59	28
49	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	44	36	61	95	57	48
50	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles . . .	67	105	32	23	83	47
51	Re-processing of secondary wood material into new wood material	29	130	47	86	84	87
52	Pulp	50	122	50	113	120	62
53	Re-processing of secondary paper into new pulp	123	122	78	93	123	96
54	Paper	70	62	29	52	69	84
55	Publishing, printing and reproduction of recorded media	89	53	72	75	110	77
56	Manufacture of coke oven products	134	133	150	140	138	43
57	Petroleum Refinery	117	83	113	118	116	144
58	Processing of nuclear fuel	53	56	23	104	78	107
59	Plastics, basic	99	89	116	112	100	45
60	Re-processing of secondary plastic into new plastic	97	93	115	85	53	51
61	N-fertiliser	134	143	141	139	141	144
62	P- and other fertiliser	106	97	32	104	86	131
63	Chemicals nec	107	71	92	110	49	119
64	Manufacture of rubber and plastic products	49	53	83	98	67	96
65	Manufacture of glass and glass products	87	60	139	123	126	144
66	Re-processing of secondary glass into new glass	90	146	117	71	115	117
67	Manufacture of ceramic goods	85	42	112	102	86	103
68	Manufacture of bricks, tiles and construction products, in baked clay	129	141	126	108	95	108
69	Manufacture of cement, lime and plaster	114	146	121	123	112	139
70	Re-processing of ash into clinker	126	143	124	129	123	96
71	Manufacture of other non-metallic mineral products n.e.c.	125	102	121	127	122	105
72	Manufacture of basic iron and steel and of ferro-alloys and first products thereof	138	120	153	136	141	131
73	Re-processing of secondary steel into new steel	136	124	149	143	138	74
74	Precious metals production	103	118	16	118	67	93
75	Re-processing of secondary precious metals into new precious metals	138	146	127	144	141	82
76	Aluminium production	127	109	114	140	135	139
77	Re-processing of secondary aluminium into new aluminium	107	124	38	101	95	59
78	Lead, zinc and tin production	121	97	65	121	126	138
79	Re-processing of secondary lead into new lead	120	128	75	118	90	135
80	Copper production	103	114	110	127	78	90
81	Re-processing of secondary copper into new copper	107	133	127	123	75	96
82	Other non-ferrous metal production	133	100	36	102	78	64
83	Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	138	146	127	144	16	51
84	Casting of metals	115	126	119	135	131	92

Table A2. Cont.

Sector ID	Sector Name	Overall Sustainability Ranking, by Country					
		Austria	China	France	Germany	Sweden	USA
85	Manufacture of fabricated metal products, except machinery and equipment	45	110	65	83	78	43
86	Manufacture of machinery and equipment n.e.c.	47	79	37	65	70	33
87	Manufacture of office machinery and computers	42	47	44	56	65	15
88	Manufacture of electrical machinery and apparatus n.e.c.	56	71	78	54	40	40
89	Manufacture of radio, television and communication equipment and apparatus	20	42	16	10	10	25
90	Manufacture of medical, precision and optical instruments, watches and clocks	12	56	42	9	19	11
91	Manufacture of motor vehicles, trailers and semi-trailers	22	66	31	53	59	28
92	Manufacture of other transport equipment	74	76	68	100	54	13
93	Manufacture of furniture; manufacturing n.e.c.	24	30	14	14	45	8
94	Recycling of waste and scrap	127	146	141	111	130	103
95	Recycling of bottles by direct reuse	138	146	141	144	141	153
96	Production of electricity by coal	138	146	153	144	132	153
97	Production of electricity by gas	138	143	153	144	138	153
98	Production of electricity by nuclear	138	112	26	75	102	139
99	Production of electricity by hydro	115	117	11	80	84	135
100	Production of electricity by wind	123	107	15	70	70	129
101	Production of electricity by petroleum and other oil derivatives	138	141	150	140	135	153
102	Production of electricity by biomass and waste	136	78	147	129	126	116
103	Production of electricity by solar photovoltaic	122	100	13	72	86	114
104	Production of electricity by solar thermal	138	146	127	144	141	123
105	Production of electricity by tide, wave, ocean	138	146	75	144	141	153
106	Production of electricity by Geothermal	129	102	127	144	141	123
107	Production of electricity nec	129	120	78	97	91	118
108	Transmission of electricity	111	110	77	96	104	130
109	Distribution and trade of electricity	99	114	54	106	33	48
110	Manufacture of gas; distribution of gaseous fuels through mains	119	133	108	20	104	113
111	Steam and hot water supply	138	146	152	137	141	151
112	Collection, purification and distribution of water	37	136	48	75	28	42
113	Construction	111	33	87	36	70	73
114	Re-processing of secondary construction material into aggregates	113	146	108	131	101	139
115	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts ...	12	22	21	6	12	3
116	Retail sale of automotive fuel	9	79	41	16	50	36
117	Wholesale trade and commission trade, except of motor vehicles and motorcycles	50	12	100	68	75	28
118	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	43	17	53	59	54	91
119	Hotels and restaurants	9	9	20	3	3	12
120	Transport via railways	77	96	73	107	70	119
121	Other land transport	74	38	90	93	108	101
122	Transport via pipelines	93	85	26	12	78	127
123	Sea and coastal water transport	38	90	141	144	114	93
124	Inland water transport	41	127	64	121	121	46
125	Air transport	117	65	147	134	116	139

Table A2. Cont.

Sector ID	Sector Name	Overall Sustainability Ranking, by Country					
		Austria	China	France	Germany	Sweden	USA
126	Supporting and auxiliary transport activities; activities of travel agencies	68	20	102	116	111	78
127	Post and telecommunications	61	48	85	56	92	119
128	Financial intermediation, except insurance and pension funding	5	114	5	4	4	4
129	Insurance and pension funding, except compulsory social security	11	44	11	6	9	5
130	Activities auxiliary to financial intermediation	15	66	25	30	11	15
131	Real estate activities	35	40	32	5	45	19
132	Renting of machinery and equipment without operator and of personal and household goods	71	60	68	98	65	105
133	Computer and related activities	6	68	18	13	5	7
134	Research and development	17	62	40	8	43	25
135	Other business activities	45	33	82	67	94	133
136	Public administration and defence; compulsory social security	3	2	6	38	7	126
137	Education	3	1	2	2	2	1
138	Health and social work	2	16	1	1	1	2
139	Incineration of waste: Food	56	81	94	31	28	83
140	Incineration of waste: Paper	53	81	94	26	22	86
141	Incineration of waste: Plastic	48	83	85	26	25	74
142	Incineration of waste: Metals and Inert materials	34	92	104	23	61	70
143	Incineration of waste: Textiles	81	85	68	47	34	78
144	Incineration of waste: Wood	74	85	83	31	28	78
145	Incineration of waste: Oil/Hazardous waste	52	85	94	26	28	78
146	Biogasification of food waste, incl. land application	72	146	62	38	28	153
147	Biogasification of paper, incl. land application	62	146	57	40	22	153
148	Biogasification of sewage sludge, incl. land application	62	146	94	26	18	53
149	Composting of food waste, incl. land application	86	93	92	33	41	84
150	Composting of paper and wood, incl. land application	59	91	57	48	141	74
151	Waste water treatment, food	81	59	103	35	43	68
152	Waste water treatment, other	77	49	106	33	41	59
153	Landfill of waste: Food	62	52	89	40	36	56
154	Landfill of waste: Paper	72	62	87	40	34	56
155	Landfill of waste: Plastic	62	69	62	40	36	64
156	Landfill of waste: Inert/metal/hazardous	59	69	106	36	25	56
157	Landfill of waste: Textiles	56	74	57	46	36	72
158	Landfill of waste: Wood	62	76	68	40	36	68
159	Activities of membership organisation n.e.c.	23	9	28	16	27	9
160	Recreational, cultural and sporting activities	25	11	44	10	54	22
161	Other service activities	1	13	18	21	8	5
162	Private households with employed persons	93	38	39	50	141	119
163	Extra-territorial organizations and bodies	138	146	153	144	141	153

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