Introducing the Recent development in input-output analysis

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Introducing the Recent Development in Input-Output Analysis

Setting the stage

This two-volume set follows up on the successful three-volume compendium of published articles on *Input-Output Analysis* edited by Heinz Kurz, Erik Dietzenbacher and Christian Lager and published by Edward Elgar in 1998. The new volumes comprehensively present research that has advanced the state of the art in input-output (IO) analysis over the past few decades, many of which have used new global data sets to focus on economic, environmental and social issues.

Volume I presents recent extensions to national accounts and international accounting, advances in the analysis of trade and global value chains, new approaches to decomposing the structures of national and international economic systems to identify proximate causes of change, and other methodological issues in the field of IO analysis. Volume II focuses on a broad swath of applications of IO analysis that have developed in interdisciplinary fields such as industrial ecology, life-cycle assessment and ecological economics, and that are consistent with the UN's System of Environmental-Economic Accounting (SEEA). In innovatively operationalizing the SEEA using ecological, resource, energy, pollution and socio-demographic databases, the work presented in Volume II convincingly demonstrates how IO analysis informs contemporary issues of environmental and social responsibility, as embedded in the Sustainable Development Goals.

What has changed in the last twenty years

Overlooking the developments in the last 20 years, it appears that two of them have been crucial for IO. First, the Kyoto Protocol and, second, the rise of international fragmentation. Under the Kyoto Protocol, a group of developed countries (the so-called Annex I countries) committed themselves to reduce the emission of greenhouse gases (GHGs). The targets were to reduce emissions down to (on average) 90% of the 1990 emission levels in the period 2008-2012 (UN, 1998). An important element of the agreement was that the targets were set for territorial emissions. Soon, people started to realize that imports could do part of the job. That is, a country could import certain goods and services that it produces in an emission intensive way. In return, this country could export goods and services that it produces in a 'clean' way, i.e. generating few emissions. Through trade this country might reduce its territorial emissions but still have the same goods and services available for further production or consumption. This is known in the literature as the displacement of emissions or carbon leakage (when dealing with CO_2 emissions).

The idea that countries (often the rich countries) might—at least in principle—be able to comply with the Kyoto targets through appropriate trading led to a different perspective on emissions. This was related to the question 'Who is ultimately responsible for the emissions?'. If the Swiss construction industry builds houses and offices with imported Italian cement (the production of which is highly polluting), who should be held responsible for the corresponding Italian emissions? Is it the Italian industry that actually produces the cement and causes the CO_2 emissions or the Swiss consumers who want new houses and work in new offices? The first case has been termed producer responsibility and the second consumer responsibility. (Also shared responsibilities have been proposed.)

The two types of responsibilities were the starting point for developing the consumption-based emission accounting (CBEA), next to the standard production-based emission accounting. The key question in CBEA is: 'Who emits how much for whom?'. Continuing the example in the previous paragraph, what is calculated are the emissions in the cement industry in Italy that are embodied in the final demand in Switzerland for houses (i.e. the products delivered by the construction industry). In this case we speak about the exports of emissions from Italy to Switzerland.

The Italian territorial emissions can be split into emissions generated by industries and emissions generated directly by households (e.g. due to driving a car). The Italian emissions by industries can be split according to ultimate destination: Italian consumers, Swiss consumers, US consumers, and so forth. In the same fashion, Italian consumption leads to emissions directly (i.e. driving a car) and to emissions generated by industries all over the world. So, Italian industries, French industries, Chinese industries, et cetera. The latter indicator is the Italian footprint, which measures all global emissions embodied in the consumption (final demands in IO parlance). The difference between the Italian territorial emissions and Italy's footprint is the emission trade balance (i.e. exports of emissions minus imports of emissions).

The methodology for applying these concepts (e.g. using CBEA and calculating footprints) was known for long. The problem was the empirical implementation, which requires global multiregional input-output (GMRIO) tables. Such tables were simply not available. For some time, researchers have tried various alternatives based on strong and unrealistic assumptions. For example, single-country models with exports to and imports from the rest-of-the-world (RoW) assuming that RoW has the same technology as the country under consideration. This assumption applies to production technology as well as the generation of emissions. Later, multi-region models for a small number of countries were used or a large set of single-country models, each with a detailed split of export destinations. Nevertheless, the quest for true multi-region models (i.e. with also a split of the inputs according to origins) at a global level remained. Davis and Caldeira (2010) is the first paper that is allegedly based on a full GMRIO table that they constructed on the basis of the GTAP database. Several other GMRIO datasets followed soon after. So, it was an important question ('Who emits how much for whom?') that urged researchers to develop GMRIO tables.

The second development that had a major influence on IO research was the rise of international fragmentation. Fragmentation meant that the production processes were split into ever smaller pieces (or stages). Many of these stages were outsourced to subcontractors or carried out by small suppliers. The international component meant that these subcontractors or suppliers were often residing in a different country. The decreases in the costs of transportation and communication (necessary for coordination) implied that distance mattered less than before. The famous example of course is the production of a cell phone. Compared to assembling the phones at home in the US, the following process became cheaper. First send the parts and components to China, then have the phones assembled by Chinese workers after which the final products are returned to the US. The gains of reducing the labor costs outweigh the extra costs due to trade and transportation.

The immediate consequence of international fragmentation was an enormous increase in trade of intermediate products. Whereas trade had been dominated in the past by trade in final products and natural resources (that were not available in the importing country), a large part was now for trade in intermediate products that entered the production process of the importing country. The implication for environmental research was that it became more important to answer the question 'Who emits how much for whom?' with GMRIO tables. Because there was much more trade in intermediates, the indirect effects in any IO analysis became much larger. Xxx and xxx report that around emissions in trade and xxxx of global emissions are traded.

The implications for trade theory were that the standard models had to be revisited so as to include trade in intermediates. The increased international fragmentation led to a different perspective on production. Producing a good or service has become more than ever a team effort. Products are no longer 'made in China' or 'made in Turkey', but rather 'made in the world'. The production process of a final good or service is seen as a supply chain that meanders from country to country, hence global supply chain. It is a chain of stages and in each stage value is added to the result of previous stages, hence global value chain (GVC). It also means that countries no longer specialize in products, rather in a certain stage of the GVC. Such a stage is typically linked to a task, hence trade in tasks (Grossman and Rossi-Hansberg, 2008).

The consequence of all this is that the ordinary trade statistics (i.e. exports and imports) do no longer tell the whole story. In the past—when 'made in the US' meant that a product was entirely made in the US—one million dollars of exports was a one million dollar increase in US value added (or GDP, at the country level). Exports thus used to reflect gains of trade, in the sense of contributing to GDP. Nowadays products are 'made in the world' and one million dollars of exports typically means much less than a one million dollar increase in GDP. This is because many countries have contributed and each earns a part of the one million dollars. Also, export and import figures contain a lot of double-counting. This is because in the stages of production certain products go back and forth between countries.

One of the relevant questions is: How much does country R contribute to (and earn from) the production of all the *final* products consumed by country S? In other words, 'Who works how much for whom?', where working stands for creating value added and 'whom' stands for the users of the final products (e.g. households and governments that consume, investors that buy capital goods). For a long time, the answer was fairly well approximated by looking at the exports from R to S. Exports were mostly final products that were made entirely in one country, so that the value of the product equaled the embodied domestic value added. Given the trade in intermediates, however, this approximation is not very adequate anymore. This is because R also participates in the GVCs for the final products that S imports from T. Using GMRIO tables we can answer the question directly. That is, calculate the value added of country R that is embodied in the final demands of country S. This is known as the export of value added from R to S (Johnson and Noguera, 2012). The OECD-WTO (2012) started the joint initiative that led to the TiVA (trade in value added) database.

Summarizing, the Kyoto Protocol and international fragmentation have led to new questions 'Who emits how much for whom?' and 'Who works how much for whom?'. These questions called for new indicators (consumption-based emission accounting and trade in value added) because the traditional indicators (territorial emissions and exports and imports) were no longer adequate and could not answer the new questions. The empirical calculation of the new indicators required the development of GMRIO tables.

Volume I: developments in accounts, methods and economic applications

In line with the introduction above, this volume starts in Part I ('**Data: Input-Output Going Globa**l') with an overview of the major GMRIO datasets that have been constructed. The special issue 'Global Multiregional Input-Output Frameworks' of *Economic Systems Research* (2013) was entirely devoted to this topic. In their introduction Tukker and Dietzenbacher (2013) point out that *the* perfect GMRIO table does not exist. Any GMRIO table hides a wealth of choices that had to be made and is full of compromises. It is therefore often the question that guides the user in selecting the dataset to use. One table has more country detail, another has a time series of tables and also provides tables in constant prices. One dataset focuses on water and land use, and has therefore much detail in the agricultural and resources industries. Another dataset focuses on employment and has therefore more detail in the services sector.

The first paper (van der Linden and Oosterhaven, 1995) is a forerunner to the GMRIO tables. It describes the construction of (one of) the first series of MRIO tables at the country level. In his PhD thesis, Van der Linden (19xx) reports on the details of the construction of and some applications with these MRIO tables. They cover 5 EU countries (Belgium, France, Germany, Italy and the Netherlands) for the years 1970, 1975, etc and 7 EU countries (the original 5 plus Denmark and the UK) for 1985, 1990, etc. In another PhD thesis, Hoen (19xx) presents the construction and application of the tables in constant prices. (All tables can be downloaded for free at https://www.rug.nl/research/reg/ research/irios/irios-tables.) The next set of papers provide information of the tables by IDE-JETRO (Meng et al., 2013), WIOD (Dietzenbacher et al., 2013), Exiobase (Tukker et al., 2009), EORA (Lenzen et al., 2012), GRAM (Bruckner et al., 2012), and a table based on GTAP (Peters et al., 2011).

Structural decomposition approaches (SDAs), the subject of Part III, were hitting their stride just as the earlier Edward Elgar volumes on *Input-Output Analysis* were released in 1998. Indeed, enough work on the topic had been completed by then to enable a review piece to be published in the journal *Economic Systems Research* (Rose & Casler, 1996). In essence, SDAs are used to explain changes in an economy over time or explain differences across economies at the same time. Differences between any two IO tables are necessarily distributed fully across the set of variables specified by the analyst (typically aspects of economy size, final demand, value added, and structure)—the effects of the components chosen are mutually exclusive and exhaustive. Moreover, two different SDA approaches are used for decomposing these four components of change—additive and multiplicative identity splitting.

Ultimately, this part kicks off with Dietzenbacher & Los (1998), who note there exist multitudes of alternative decompositions for a given analytical focus (outcome and set of factors). In fact they note if *n* factors are applied then *n*!(factorial) alternative decompositonal forms should be examined.[1] They then assure readers that the average of the two polar decompositions very closely approximates the average of all possible *n*! alternatives. They conclude their work by recommending researchers should report the average effects as well as the ranges by using the two polar decompositions. De Haan (2001) notes that full count of the average of any mirror decompositions rather than only of extreme polar decompositions is sufficient to get the average of all decompositions. Another nice feature of De Haan (2001) provides is a set of tables that are price-chained, that is in both current prices and in subsequent years prices. This practice of price chaining tables for handling prices is important since it is subsequently adopted in some of the world IO databases discussed elsewhere in this Introduction.

Although probably first introduced by Oosterhaven and van der Linden (1997), we include here a piece by Oosterhaven and Hoen (1998) due to its focus on trade issues. Building on the multiplicative identity splitting approach work of Dietzenbacher, Hoen, and Los (2000) and Yang and Lahr (2008), Jiang, Dietzenbacher, and Los (2014) holds similar value to Oosterhaven and Hoen, but at a subnational level. In addition to examining interregional trade effects, they develop an approach that is more akin to shift-share analysis (SSA) in that it contrasts each region to a national average, which in turn enables multilateral comparisons. Later work by Lahr and Dietzenbacher (2017) extends this work and fully melds SDA with SSA.

The piece by Xia, Fan and Yang (2015) also leans on the approach by Dietzenbacher, Hoen, and Los (2000), but examines CO_2 emissions using IO tables of China that not only distinguish processing (assembly) operations from other traditional operations within manufacturing industries but also include physical energy flows. The object of using the three-way (or tripartite) tables in this piece is to delineate low value-added, export-based transactions, which largely engage imports from abroad as inputs, from higher value-added transactions, which are more apt to be used domestically as well as to use as inputs domestically produced goods—including CO_2-generating electricity, coal, and oil.

1 Van der Kruk (1999) notes that even more than n! decompositions exist if all interaction terms are taken into account.

Policy applications of SDA are seemingly boundless. Further, Lahr and Dietzenbacher (2017) note that analysts do not even need two IO tables to apply it. Their work does suggest, however, that economic geographic components of such tables—like final demand composition and GDP by industry—are likely to be required to investigate conventional issues like changes in worker productivity, energy usage, or greenhouse gas emissions.

Part IV, "**Structural Change and Productivity**" starts with ten Raa and Wolff (2001). They use SDA to find evidence of Carter's (1970) and Barker's (1990) idea that some apparent manufacturing productivity growth could arise because the sector sheds less-productive in-house services, which also exaggerates the symptoms of Baumol's (1967) disease. This is followed by Amores and ten Raa (2014) who use establishment-level IO information and data envelopment analysis (DEA) (Charnes et al., 1995) to decompose an economy's potential efficiency gains via three possible sources: by firms attaining their industry's best practice technology, changes in the economy's industry mix, and perfect commodity specialization by industry. Kuroda and Nomura (2004) examine the deep, temporal interindustry effects of industry efficiency gains via both static production linkages (Peterson, 1979; Wolff, 1985) and dynamic production linkages (Aulin-Ahmavaara, 1999). They show, for example, how early investments in Japan's machine tool industry lead to efficiencies that later enable the nation's auto manufacturers to compete on an international scale. Such interindustry dynamics are certainly compelling. For this reason, we also include an empirical piece by Okuyama, Sonis and Hewings (2006) who decompose a direct requirements matrix into its value in a base year and subsequent annual changes to it. The approach, formally developed by Sonis and Hewings (1998), proposes a temporal inverse that can effectively reveal how an economy evolved using a single year of the economy's final demand. This part ends with Israilevich et al. (1997), who integrate IO systems with a macroeconomic forecasting model along the lines of Almon's (1967) INFORUM models although more akin to Conway (1990) and Kratena and Zakarias (2004). Although not included herein, we also point the interested reader to Israilevich (2002) who hints how to constrain IO coefficients by relative prices as embedded in value added (cf. Hudson and Jorgenson, 1974; Nakamura, 1984) as well as by final demand and output.

Volume II: Environment and Resources in input-output analysis

Volume II extends the more general topics covered in Volume I, by providing insights and an overview of how input-output analysis has been applied to environmental and resource issues. Without doubt, contemporary resource depletion and related environmental woes have spurred a renaissance in the application of input-output analysis (Hoekstra 2010), which in turn is largely responsible for the increasing popularity of and relevance of papers in *Economic Systems Research*, *Ecological Economics*, *Journal of Industrial Ecology*, *Journal of Cleaner Production*, *Environmental Science & Technology*, and others. For example, recognizing the strong cross-fertilisation of their respective fields, the Industrial Ecology and Input-Output associations have been running their conferences back-to-back for a number of years. Disciplines such as Life-Cycle Assessment and environmental footprinting now routinely utilize input-output techniques in their repertoire. As, or because environmental and resource problems are expected to worsen, this disciplinary integration is expected to deepen in the future (Dietzenbacher *et al.* 2013; Lenzen 2014). In the presentation of Volume II below, I will provide some references that go beyond what is included in this Volume – they may assist the reader in appreciating that the representative literature extends beyond our selection, and in suggesting further reading.

The introduction in part I reflects the brief account given in the preceding paragraph, in that it highlights four physical science areas in which economic input-output analysis has made significant contributions. They are Industrial Ecology and Life-Cycle Assessment (Duchin 1992; Suh and Kagawa 2005), Sustainable Consumption (Hertwich 2005; Hertwich 2010) and Physical Input-

Output Analysis (Hubacek and Giljum 2003; Giljum and Hubacek 2004; Giljum *et al.* 2004; Suh 2004b; Dietzenbacher 2005; Weisz and Duchin 2006). Part II provides a historical background, including classical papers such as Isard's early innovation of a coupled ecological-economic model (Isard *et al.* 1967), Daly's and Ayres' conceptual foundations for a physical-economic framework integration (Daly 1968; Ayres and Kneese 1969), Leontief's first foray into environmental questions (Leontief and Ford 1970; 1971), Hannon's theoretical description of ecosystem metabolism (Hannon 1973; 1979; 1985; Hannon *et al.* 1986; Hannon 1995), and early attempts at standardization of extended IO systems (de Haan and Keuning 1996; Ike 1999; Keuning *et al.* 1999; Vaze 1999; EC 2001), which ultimately lead to the development of the SEEA (UNSD 2017).

Part III deals with resources and energy, both of which are responsible for IOA's first popularity boom, coinciding with the energy crises of the 1970s (Herendeen 1973; Herendeen and Sebald 1973; Chapman 1974b; a; Chapman *et al.* 1974; Herendeen 1974; Hirst 1974; Mazur and Rose 1974; Bullard and Herendeen 1975; Chapman 1975; Leach 1975; Webb and Pearce 1975; Bullard 1976; Chapman 1976; Herendeen and Tanaka 1976). Graham Treloar's study on embodied-energy paths (Treloar 1997) remains highly cited to date. Hubacek and Giljum 2003, Feng *et al.* 2011 and Wiedmann *et al.* 2015b were the forerunners of global MRIO analyses in terms of land, water and materials. Part IV then turns to the second popularity boom, conciding with the increasing recognition of climate change as the defining problem of our time (Minx *et al.* 2009). Munksgaard and Pedersen 2001 brought up the question of responsibility, an issue that has since proliferated and lively debate, and that is at the core of annual negotiations at the UN FCCC's Conferences of the Parties (COPs). A prominent theme within this nexus is what has been described by terms such as "carbon leakage", "international emission transfers" or "outsourcing" (Peters 2010; Wiedmann *et al.* 2010; Peters *et al.* 2011; Jakob and Marschinski 2012; Feng *et al.* 2013; Hoekstra *et al.* 2016; Malik and Lan 2016).

Part V demonstrates the versatility of input-output techniques in operating in terms of any additive physical quantity that can be allocated to regions and sectors, be they waste flows (Nakamura 2000; Dietzenbacher 2005; Nakamura *et al.* 2007; Lenzen and Reynolds 2014), trophic chains (Hannon 1973; Odum 1973; Patten *et al.* 1976; Rapport and Turner 1977; Bernstein 1981; Patten 1985; Szyrmer and Ulanowicz 1987; Herendeen 1991; Hannon 1995; Herendeen 1999; Suh 2005; Lenzen 2006), nitrogen (Wier and Hasler 1999; Cui *et al.* 2016; Oita *et al.* 2016) or mercury (Hui *et al.* 2017). Part VI equally demonstrates IOA's versatility, but this time in respect of regional resolution. Despite the labour-intensive nature of assembling sub-national multi-regional input-output databases, a number of teams have made significant inroads in characteristing sub-national flows in terms of water (Dietzenbacher and Velázquez 2007; Guan and Hubacek 2007; Velázquez 2007; Lenzen 2009; Yu *et al.* 2010; Daniels *et al.* 2011; Feng *et al.* 2012; Cazcarro *et al.* 2013a; Cazcarro *et al.* 2013b), energy and carbon footprints of cities (Lenzen and Peters 2010; Minx *et al.* 2013; Hasegawa *et al.* 2015; Wiedmann *et al.* 2015a; Fry *et al.* 2018), and regional waste flows (Tsukui *et al.* 2015).

Part VII delves into detail about the successful integration of input-output techniques into Life-Cycle Assessment. Applications here are far too numerous to receive a fair and comprehensive review; we have included a few diverse contributions, for example by Sangwon Suh (see also Heijungs and Suh 2002; Suh 2004a; Suh *et al.* 2004; Suh and Huppes 2005), Shigemi Kagawa and Keisuke Nansai (see also Nansai *et al.* 2001; Kagawa 2005; Nansai 2005; Nansai *et al.* 2009; Kagawa *et al.* 2011; Nansai *et al.* 2014; Nansai *et al.* 2015). Part VIII shows how input-output techniques can elucidate trends and drivers of environmental and resource change. Prominent tools here are Structural Decomposition Analysis (SDA; Crama *et al.* 1984; Hoekstra and van den Bergh 2002; 2003; Dietzenbacher and Stage 2006; Weinzettel and Kovanda 2011; Owen *et al.* 2014; Xu and Dietzenbacher 2014; Zhang and Lahr 2014a; b; Lan *et al.* 2016) and Structural Path Analysis (SPA;

Defourny and Thorbecke 1984; Khan and Thorbecke 1989; Sonis *et al.* 1997; Fernández-Vázquez *et al.* 2008; Lenzen and Crawford 2009; Wood and Lenzen 2009; Owen *et al.* 2016).

The relevance of input-output-related research would remain limited without salient policy applications, which are the topic of part IX. In this respect are especially noteworthy the insights that IO research has contributed to allocating responsibility for carbon emissions (Feng *et al.* 2010; Barrett *et al.* 2013; Wiedmann and Barrett 2013). This also holds for organisational decision-making, to which IO research can contribute (Wiedmann *et al.* 2009; Baboulet and Lenzen 2010; Lenzen *et al.* 2010). The final part X touches on very recent developments on including social impacts into IO analyses (McBain and Alsamawi 2014; McBain 2015; Alsamawi *et al.* 2017a; Malik *et al.* 2018). Social indicators are important if IO research is to be relevant for informing the Sustainable Development Goals (Xiao *et al.* 2017). Here, new indicators include problematic labour (Simas *et al.* 2014; Gómez-Paredes *et al.* 2016), inequality (Alsamawi *et al.* 2014; Reyes *et al.* 2017), corruption (Xiao *et al.* 2016), conflict (Moran *et al.* 2015; Tisserant and Pauliuk 2016), or occupational hazards (Alsamawi *et al.* 2017b).

References

Grossman, G.M. and Rossi-Hansberg, E. (2008) Trading tasks: a simple theory of offshoring, *American Economic Review*, 98, 1978-1997.

Johnson, R.C. and Noguera, G. (2012) Accounting for intermediates: production sharing and trade in value added, *Journal of International Economics*, 86, 224–236.

OECD-WTO (2012) Measuring Trade in Value-Added: an OECD-WTO Joint Initiative, Available at: http://www.oecd.org/sti/industryandglobalisation/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

United Nations (UN) (1998) The Kyoto protocol to the United Nations framework convention on climate change, Available at: http://unfccc.int/resource/docs/convkp/kpeng.pdf.

Almon, C. (1967) *The American Economy to 1975*. New York: Harper & Row.

Alsamawi, A., D. McBain, J. Murray, M. Lenzen and K.S. Wiebe (2017a) *The Social Footprints of Global Trade*. Berlin, Germany, Springer.

Alsamawi, A., J. Murray, M. Lenzen, K. Kanemoto and D. Moran (2014) A novel approach to quantitative accounting of income inequality. *PLOS ONE* 9, e110881.

Alsamawi, A., J. Murray, M. Lenzen and R.C. Reyes (2017b) Trade in occupational safety and health: Tracing the embodied human and economic harm in labour along the global supply chain. *Journal of Cleaner Production*.

Aulin-Ahmavaara, P. (1999) Effective rates of sectoral productivity change. *Economic Systems Research* 11, 349-363.

Ayres, R.U. and A.V. Kneese (1969) Production, consumption, and externalities. *American Economic Review* 59, 282-297.

Baboulet, O. and M. Lenzen (2010) Evaluating the environmental performance of a university. *Journal of Cleaner Production* 18, 1134-1141.

Barker, T. (1990) Sources of structural change for the UK service industries 1979–84. *Economic Systems Research* 2, 173–183.

Barrett, J., G. Peters, T. Wiedmann, K. Scott, M. Lenzen, K. Roelich and C. Le Quéré (2013) Consumption-based GHG emission accounting: a UK case study. *Climate Policy* 13, 451-470.

Baumol, W. J. (1967) Microeconomics of unbalanced growth: the anatomy of urban crisis *American Economic Review* 57, 415–426.

Bernstein, B.B. (1981) Ecology and economics. *Anual Review of Ecological Systems* 12, 309-330.

Bullard, C.W. (1976) Energy costs and benefits; net energy. *Energy Systems and Policy* 1, 367-382.

Bullard, C.W. and R.A. Herendeen (1975) The energy cost of goods and services. *Energy Policy* 3, 268–278.

Cazcarro, I., R. Duarte and J. Sánchez Chóliz (2013a) Multiregional input–output model for the evaluation of Spanish water flows. *Environmental Science & Technology* 47, 12275-12283.

Cazcarro, I., R. Duarte and J. Sánchez-Chóliz (2013b) Water Footprints for Spanish Regions Based on a Multi-Regional Input-Output (MRIO) Model. In: J. Murray and M. Lenzen (eds.) *The Sustainability Practitioner's Guide to Multi-Regioal Input-Output Analysis*. Champaign, USA, Common Ground, 119-132.

Carter, A. P. (1970) *Structural Change in the American Economy*. Cambridge, Mass.: Harvard University Press.

Chapman, P.F. (1974a) Energy analysis of nuclear power stations. *Energy Policy* 3, 285-299.

Chapman, P.F. (1974b) Energy costs: a review of methods. *Energy Policy* 2, 91-102.

Chapman, P.F. (1975) The energy costs of materials. *Energy Policy* 3, 47-57.

Chapman, P.F. (1976) Methods of energy analysis. In: I.M. Blair, B.D. Jones and A.J. Van Horn (eds.) *Aspects of Energy Conversion*. Oxford, UK, Pergamon Press, 739-758.

Chapman, P.F., G. Leach and M. Slesser (1974) The energy cost of fuels. *Energy Policy* 2, 231-243.

Charnes A., W.W. Cooper, A. Lewin and L. Seiford. (1995) *Data Envelopment Analysis: Theory, Methodology and Applications*. Kluwer Academic Publishers: Dordrecht, Netherlands.

Conway, R. S. (1990) The Washington projection and simulation model: a regional interindustry econometric model. *International Regional Science Review* 13, 141-166.

Crama, Y., J. Defourny and J. Gazon (1984) Structural decomposition of multipliers in input-output or social accounting matrix analysis. *Economie Appliquée* 37, 215-222.

Cui, S., Y. Shi, A. Malik, M. Lenzen, B. Gao and W. Huang (2016) A hybrid method for quantifying China's nitrogen footprint during urbanisation from 1990 to 2009. *Environment International* 97, 137-145.

Daly, H.E. (1968) On economics as a life science. *Journal of Political Economy* 76, 392-406.

Daniels, P.L., M. Lenzen and S.J. Kenway (2011) The ins and outs of water use – A review of multi-region input–output analysis and water footprints for regional sustainability analysis and policy. *Economic Systems Research* 23, 353-370.

de Haan, M. and S.J. Keuning (1996) Taking the environment into account: the NAMEA approach. *Review of Income and Wealth* 42, 131-148.

Defourny, J. and E. Thorbecke (1984) Structural path analysis and multiplier decomposition within a social accounting matrix framework. *Economic Journal* 94, 111-136.

Dietzenbacher, E. (2005) Waste treatment in physical input-output analysis. *Ecological Economics* 55, 11-23.

Dietzenbacher, Erik, Alex R. Hoen, and Bart Los. (2000) "Labor Productivity in Western Europe 1975-1985: An Intercountry, Interindustry Analysis," *Journal of Regional Science*, 40, 425–452

Dietzenbacher, Erik, Michael L. Lahr and Bart Los (2004) "The decline in labor compensation's share of GDP: a structural decomposition analysis for the US, 1982-1997," in: Erik Dietzenbacher and Michael. L. Lahr (eds) *Wassily Leontief and Input-Output Economics* (Cambridge University Press, Cambridge), pp. 188-212.

Dietzenbacher, E., M. Lenzen, B. Los, D. Guan, M.L. Lahr, F. Sancho, S. Suh and C. Yang (2013) Input–output analysis: The next 25 years. *Economic Systems Research* 25, 369-389.

Dietzenbacher, Erik and Bart Los. (1998). "Structural decomposition techniques: sense and sensitivity." *Economic Systems Research*, 10, 307-324.

Dietzenbacher, E. and J. Stage (2006) Mixing oil and water? Using hybrid input-output tables in a structural decomposition analysis. *Economic Systems Research* 18, 85-95.

Dietzenbacher, E. and E. Velázquez (2007) Analysing Andalusian virtual water trade in an input–output framework. *Regional Studies* 41, 1-12.

Duchin, F. (1992) Industrial input-output analysis: implications for industrial ecology. *Proceedings of the National Academy of Science of the USA* 89, 851-855.

EC (2001) *NAMEAs for air emissions: Results of pilot studies*. Luxembourg, Luxembourg, European Communities.

Feng, K., A.K. Chapagain, S. Suh, S. Pfister and K. Hubacek (2011) Comparison of bottom-up and top-down approaches to calculating the water footprints of nations. *Economic Systems Research* 23, 371-385.

Feng, K., S.J. Davis, L. Sun, X. Li, D. Guan, W. Liu, Z. Liu and K. Hubacek (2013) Outsourcing CO2 within China. *Proceedings of the National Academy of Sciences* 110, 11654-11659.

Feng, K., K. Hubacek, D. Guan, M. Contestabile, J. Minx and J. Barrett (2010) Distributional effects of climate change taxation: the case of the UK. *Environmental Science & Technology* 44, 3670-3676.

Feng, K., Y.L. Siu, D. Guan and K. Hubacek (2012) Assessing regional virtual water flows and water footprints in the Yellow River Basin, China: A consumption based approach. *Applied Geography* 32, 691-701.

Fernández-Vázquez, E., B. Los and C. Ramos-Carvajal (2008) Using Additional Information in Structural Decomposition Analysis: The Path-based Approach. *Economic Systems Research* 20, 367-394.

Fry, J., M. Lenzen, Y. Jin, T. Wakiyama, T. Baynes, T. Wiedmann, A. Malik, G. Chen, Y. Wang, A. Geschke and H. Schandl (2018) Assessing carbon footprints of cities under limited information. *Journal of Cleaner Production* 176, 1254-1270.

Giljum, S. and K. Hubacek (2004) Alternative approaches of physical input-output analysis to estimate primary material inputs of production and consumption activities. *Economic Systems Research* 16, 301-310.

Giljum, S., K. Hubacek and L. Sun (2004) Beyond the simple material balance: a reply to Sangwon Suh's note on physical input-output analysis. *Ecological Economics* 48, 19-22.

Gómez-Paredes, J., A. Alsamawi, E. Yamasue, H. Okumura, K.N. Ishihara, A. Geschke and M. Lenzen (2016) Consuming Childhoods: An Assessment of Child Labor's Role in Indian Production and Global Consumption. *Journal of Industrial Ecology* 20, 611-622.

Guan, D. and K. Hubacek (2007) Assessment of regional trade and virtual water flows in China. *Ecological Economics* 61, 159-170.
Hannon, B. (1973) The structure of ecosystems. *Journal of Theoretical Biology* 41, 535-546.
Hannon, B. (1979) Total energy cost in ecosystems. *Journal of Theoretical Biology* 80, 272-293.
Hannon, B. (1985) Linear dynamic ecosystems. *Journal of Theoretical Biology* 116, 89-110.
Hannon, B. (1995) Input-output economics and ecology. *Structural Change and Economic Dynamics* 6, 331-333.
Hannon, B., R. Costanza and R.A. Herendeen (1986) Measures of energy cost and value in ecosystems. *Journal of Environmental Economics and Management* 13, 391-401.
Hasegawa, R., S. Kagawa and M. Tsukui (2015) Carbon footprint analysis through constructing a multi-region input–output table: a case study of Japan. *Journal of Economic Structures* 4, 1-20.
Heijungs, R. and S. Suh (2002) *The computational structure of life cycle assessment*. Dordrecht, Netherlands, Kluwer Academic Publishers.
Herendeen, R. (1991) Do economics-like principles predict ecosystem behaviour under changing resource constraints? In: M. Higashi and T.P. Burns (eds.) *Theoretical studies of ecosystems*. Cambridge, UK, Cambridge University Press, 261-287.
Herendeen, R. and J. Tanaka (1976) Energy cost of living. *Energy* 1, 165-178.
Herendeen, R.A. (1973) Use of input-output analysis to determine the energy cost of goods and services. In: M.S. Macrakis (ed.) *Energy: Demand, Conservation, and Institutional Problems*. Cambridge, MA, USA, Massachusetts Institute of Technology, 141-158.
Herendeen, R.A. (1974) Affluence and energy demand. *Mechanical Engineering* 96, 18-22.
Herendeen, R.A. (1999) EMERGY, value, ecology and economics. In: J.C.J.M. van den Bergh (ed.) *Handbook of Environmental and Resource Economics*. Cheltenham, UK, Edward Elgar, 954-964.
Herendeen, R.A. and A. Sebald (1973) *The dollar, energy and employment impacts of certain consumer options*. Preliminary Report to the Ford Foundation, Urbana, IL, USA, Center for Advanced Computation, University of Illinois.
Hertwich, E.G. (2005) Consumption and Industrial Ecology. *Journal of Industrial Ecology* 9, 1-6.
Hertwich, E.G. (2010) The life-cycle environmental impacts of consumption. *Economic Systems Research* 23, 27-47.
Hirst, E. (1974) Food-related energy requirements. *Science* 184, 134-138.
Hoekstra, R. (2010) (Towards) a complete database of peer-reviewed articles on environmentally extended input-output analysis. In: J.M. Rueda-Cantuche and K. Hubacek (eds.) *18th International Input-Output Conference,* http://www.iioa.org/files/conference-1/37_20100617021_Lenen&al_GlobalMRIO_18thIOConf2010.pdf. Sydney, Australia.
Hoekstra, R., B. Michel and S. Suh (2016) The emission cost of international sourcing: Using Structural Decomposition Analysis to calculate the contribution of international sourcing to CO2-emission growth. *Economic Systems Research* 28, 151-167.
Hoekstra, R. and J.C.J.M. van den Bergh (2002) Structural decomposition analysis of physical flows in the economy. *Environmental and Resource Economics* 23, 357-378.
Hoekstra, R. and J.C.J.M. van den Bergh (2003) Comparing structural and index decomposition analysis. *Energy Economics* 25, 39-64.

Hubacek, K. and S. Giljum (2003) Applying physical input-output analysis to estimate land appropriation (ecological footprints) of international trade activities. *Ecological Economics* 44, 137-151.

Hudson, E. and D. W. Jorgenson (1974) US energy policy and economic growth, 1975-2000. *Bell Journal of Economics* 5, 461-514.

Hui, M., Q. Wu, S. Wang, S. Liang, L. Zhang, F. Wang, M. Lenzen, Y. Wang, L. Xu, Z. Lin, H. Yang, Y. Lin, T. Larssen, M. Xu and J. Hao (2017) Mercury flows in China and global drivers. *Environmental Science & Technology* 51, 222-231.

Ike, T. (1999) A Japanese NAMEA. *Structural Change and Economic Dynamics* 10, 123-149.

Isard, W., K. Bassett, C. Choguill, J. Furtado, R. Izumita, J. Kissin, E. Romanoff, R. Seyfarth and R. Tatlock (1967) On the linkage of socio-economic and ecologic systems. *Papers and Proceedings of the Regional Science Association* 21, 79-99.

Jakob, M. and R. Marschinski (2012) Interpreting trade-related CO2 emission transfers. *Nature Climate Change* 3, 19.

Jiang, Xuemei, Erik Dietzenbacher, and Bart Los. (2014) A dissection of the growth of regional disparities in Chinese labor productivity between 1997 and 2002. *Annals of Regional Science* 52, 513-536.

Kagawa, S. (2005) Inter-industry analysis, consumption structure, and the household waste production structure. *Economic Analysis and Policy* 17, 409-423.

Kagawa, S., K. Nansai, Y. Kondo, K. Hubacek, S. Suh, J. Minx, Y. Kudoh, T. Tasaki and S. Nakamura (2011) Role of Motor Vehicle Lifetime Extension in Climate Change Policy. *Environmental Science & Technology* 45, 1184-1191.

Keuning, S.J., J. van Dalen and M. de Haan (1999) The Netherlands 'NAMEA'; presentation, usage and future extensions. *Structural Change and Economic Dynamics* 10, 15-37.

Khan, H.A. and E. Thorbecke (1989) Macroeconomic effects of technology choice: multiplier and structural path analysis within a SAM framework. *Journal of Policy Modeling* 11, 131-156.

Kratena, K. and G. Zakarias (2004) Input coefficient change using biproportional econometric adjustment functions. *Economic Systems Research* 16, 191-203.

Lahr, Michael L. and Erik Dietzenbacher. (2017). "Structural Decomposition and Shift-Share Analyses: Let the Parallels Converge." In Randall Jackson and Peter Schaeffer (eds), *Regional Research Frontiers*, Vol. 2. (Springer: Cham, Switzerland), pp. 209-220.

Lan, J., A. Malik, M. Lenzen, D. McBain and K. Kanemoto (2016) A structural decomposition analysis of global energy footprints. *Applied Energy* 163, 436-451.

Leach, G. (1975) Net energy analysis - is it any use? *Energy Policy* 3, 332-344.

Lenzen, M. (2006) Structural Path Analysis of ecosystem networks. *Ecological Modelling* 200, 334-342.

Lenzen, M. (2009) Understanding virtual water flows – a multi-region input-output case study of Victoria. *Water Resources Research* 45, W09416.

Lenzen, M. (2014) An outlook into a possible future of footprint research. *Journal of Industrial Ecology* 18, 4-6.

Lenzen, M., C. Benrimoj and B. Kotic (2010) Input-output analysis for business planning: A case study of the University of Sydney. *Economic Systems Research* 22, 155-179.

Lenzen, M. and R.H. Crawford (2009) The path exchange method for hybrid LCA. *Environmental Science & Technology* 43, 8251-8256.

Lenzen, M. and G. Peters (2010) How city dwellers affect their resource hinterland – a spatial impact study of Australian households. *Journal of Industrial Ecology* 14, 73-90.

Lenzen, M. and C.J. Reynolds (2014) A Supply-Use Approach to Waste Input-Output Analysis. *Journal of Industrial Ecology* 18, 212-226.

Leontief, W. and D. Ford (1970) Environmental repercussions and the economic structure: an input-output approach. *Review of Economics and Statistics* 52, 262-271.

Leontief, W. and D. Ford (1971) *Air pollution and the economic structure: empirical results of input-output computations*. Geneva, Switzerland, North-Holland Publishing Company.

Malik, A. and J. Lan (2016) The role of outsourcing in driving global carbon emissions. *Economic Systems Research* 28, 168-182.

Malik, A., D. McBain, T.O. Wiedmann, M. Lenzen and J. Murray (2018) Advancements in Input-Output models and indicators for Consumption-Based Accounting. *Journal of Industrial Ecology*, https://doi.org/10.1111/jiec.12771.

Mazur, A. and E. Rose (1974) Energy and life-style. *Science* 186, 607-610.

McBain, D. (2015) Is Social Footprinting Relevant to Industrial Ecology? *Journal of Industrial Ecology* 19, 340-342.

McBain, D. and A. Alsamawi (2014) Quantitative accounting for social economic indicators. *Natural Resources Forum* 38, 193-202.

Minx, J., T. Wiedmann, R. Wood, G.P. Peters, M. Lenzen, A. Owen, K. Scott, J. Barrett, K. Hubacek, G. Baiocchi, A. Paul, E. Dawkins, J. Briggs, D. Guan, S. Suh and F. Ackerman (2009) Input-output analysis and carbon footprinting: An overview of applications. *Economic Systems Research* 21, 187-216.

Minx, J.C., G. Baiocchi, T. Wiedmann, J. Barrett, F. Creutzig, K. Feng, M. Förster, P.-P. Pichler, H. Weisz and K. Hubacek (2013) Carbon footprints of cities and other human settlements in the UK. *Environmental Research Letters* 8, 035039.

Moran, D., D. McBain, K. Kanemoto, M. Lenzen and A. Geschke (2015) Global Supply Chains of Coltan. *Journal of Industrial Ecology* 19, 357-365.

Munksgaard, J. and K.A. Pedersen (2001) CO_2 accounts for open economies: producer or consumer responsibility? *Energy Policy* 29, 327-334.

Nakamura, S. (1984) *An Inter-Industry Translog Model of Prices and Technical Change for the West German Economy*. Berlin: Springer-Verlag.

Nakamura, S. (2000) Input-output analysis of waste management. *Waste Management Research* 11, 289-300 (in Japanese).

Nakamura, S., K. Nakajima, Y. Kondo and T. Nagasaka (2007) The Waste Input-Output approach to Material Flow Analysis: Concepts and application to base metals. *Journal of Industrial Ecology* 11, 50-63.

Nansai, K. (2005) Site-dependent Life-Cycle Analysis by the SAME approach: Its concept, usefulness, and application to the calculation of embodied impact intensity by means of an input-output analysis. *Environmental Science & Technology* 39, 7318 - 7328.

Nansai, K., S. Kagawa, Y. Kondo, S. Suh, R. Inaba and K. Nakajima (2009) Improving the completeness of product carbon footprints using a global link input-output model: the case of Japan. *Economic Systems Research* 21, 267-290.

Nansai, K., K. Nakajima, S. Kagawa, Y. Kondo, Y. Shigetomi and S. Suh (2015) Global mining risk footprint of critical metals necessary for low-carbon technologies: the case of neodymium, cobalt, and platinum in Japan. *Environmental Science & Technology* 49, 2022-2031.

Nansai, K., K. Nakajima, S. Kagawa, Y. Kondo, S. Suh, Y. Shigetomi and Y. Oshita (2014) Global flows of critical metals necessary for low-carbon technologies: the case of neodymium, cobalt, and platinum. *Environmental Science & Technology* 48, 1391-1400.

Nansai, K., S. Tohno, M. Kono, M. Kasahara and Y. Moriguchi (2001) Life-cycle analysis of charging infrastructure for electric vehicles. *Applied Energy* 70, 251-265.

Odum, H.T. (1973) Energy, ecology, and economics. *Ambio* 2, 220-227.

Oita, A., A. Malik, K. Kanemoto, A. Geschke, S. Nishijima and M. Lenzen (2016) Substantial nitrogen pollution embedded in international trade. *Nature Geoscience* 9, 111-115.

Oosterhaven, Jan, and Alex R. Hoen. (1998) Preferences, technology, trade and real income changes in the European Union An intercountry decomposition analysis for 1975–1985. *Annals of Regional Science,* 32, 505-524.

Oosterhaven, Jan and Jan A. Van Der Linden. (1997) European technology, trade and income changes for 1975–85: an intercountry input–output decomposition. *Economic Systems Research,* 9, 393-412.

Owen, A., K. Steen-Olsen, J. Barrett, T. Wiedmann and M. Lenzen (2014) A structural decomposition approach to comparing MRIO databases. *Economic Systems Research* 26, 262-283.

Owen, A., R. Wood, J. Barrett and A. Evans (2016) Explaining value chain differences in MRIO databases through structural path decomposition. *Economic Systems Research* 28, 1-30.

Patten, B.C. (1985) Energy cycling in the ecosystem. *Ecological Modelling* 28, 1-71.

Patten, B.C., R.W. Bosserman, J.T. Finn and W.G. Cale (1976) Propagation of cause in ecosystems. In: B.C. Patten (ed.) *Systems Analysis and Simulation in Ecology*. New York, NY, USA, Academic Press, 457-579.

Peters, G. (2010) Managing carbon leakage. *Carbon Management* 1, 35-37.

Peters, G., J. Minx, C. Weber and O. Edenhofer (2011) Growth in emission transfers via international trade from 1990 to 2008. *Proceedings of the National Academy of Sciences of the United States of America* 108, 8903–8908.

Peterson, W. (1979) Total factor productivity in the UK: a disaggregated analysis. In K. D. Patterson and K. Schott (eds), *The Measurement of Capital*, Palgrave Macmillan, London, pp. 212-225.

Rapport, D.J. and J.E. Turner (1977) Economic models in ecology. *Science* 195, 367-373.

Reyes, R.C., M. Lenzen and J. Murray (2017) Better Global Assessment of Worker Inequality: Comment on "The Employment Footprints of Nations". *Journal of Industrial Ecology* 21, 1188-1197.

Rose, Adam and Stephen Casler. (1996). "Input–output structural decomposition analysis: a critical appraisal," *Economic Systems Research*, 8, 33-62.

Simas, M., L. Golsteijn, M. Huijbregts, R. Wood and E. Hertwich (2014) The "Bad Labor" Footprint: Quantifying the Social Impacts of Globalization. *Sustainability* 6, 7514.

Sonis, M. and G.J.D. Hewings. (1998) Temporal Leontief inverse, *Macroeconomic Dynamics* 2, 89–114.

Sonis, M., G.J.D. Hewings and S. Sulistyowati (1997) Block structural path analysis: applications to structural changes in the Indonesian economy. *Economic Systems Research* 9, 265-280.

Su, Bin and Beng W. Ang. (2012). "Structural decomposition analysis applied to energy and emissions: some methodological developments." *Energy Economics*, 34, 177-188.

Suh, S. (2004a) Functions, commodities and environmental impacts in an ecological-economic model. *Ecological Economics* 48, 451-467.

Suh, S. (2004b) A note on the calculus for physical input-output analysis and its application to land appropriation of international trade activities. *Ecological Economics* 48, 9-17.

Suh, S. (2005) Theory of materials and energy flow analysis in ecology and economics. *Ecological Modelling* 189, 251-269.

Suh, S. and G. Huppes (2005) Methods for Life Cycle Inventory of a product. *Journal of Cleaner Production* 13, 687-697.

Suh, S. and S. Kagawa (2005) Industrial ecology and input-output economics: an introduction. *Economic Systems Research* 17, 349-364.

Suh, S., M. Lenzen, G.J. Treloar, H. Hondo, A. Horvath, G. Huppes, O. Jolliet, U. Klann, W. Krewitt, Y. Moriguchi, J. Munksgaard and G. Norris (2004) System boundary selection in Life-Cycle Inventories. *Environmental Science & Technology* 38, 657-664.

Szyrmer, J.M. and R.E. Ulanowicz (1987) Total flows in ecosystems. *Ecological Modelling* 35, 123-136.

Tisserant, A. and S. Pauliuk (2016) Matching global cobalt demand under different scenarios for co-production and mining attractiveness. *Journal of Economic Structures* 5, 1-19.

Treloar, G. (1997) Extracting embodied energy paths from input-output tables: towards an input-output-based hybrid energy analysis method. *Economic Systems Research* 9, 375-391.

Tsukui, M., S. Kagawa and Y. Kondo (2015) Measuring the waste footprint of cities in Japan: an interregional waste input–output analysis. *Journal of Economic Structures* 4, 1-24.

UNSD (2017) *System of Environmental- Economic Accounting— SEEA Revision*. Internet site https://unstats.un.org/unsd/envaccounting/seearev/, United Nations.

Van der Kruk, R. (1999). "Decomposition uniqueness: the basic additive identity splitting method,“ unpublished paper presented at the workshop *Thoughts on input-output decomposition analysis*. (Tinbergen Institute: Amsterdam).

Vaze, P. (1999) A NAMEA for the UK. *Structural Change and Economic Dynamics* 10, 99-121.

Velázquez, E. (2007) Water trade in Andalusia. Virtual water: An alternative way to manage water use. *Ecological Economics* 63, 201-208.

Webb, M. and D. Pearce (1975) The economics of energy analysis. *Energy Policy* 3, 318-331.

Weinzettel, J. and J. Kovanda (2011) Structural Decomposition Analysis of Raw Material Consumption. *Journal of Industrial Ecology* 15, 893-907.

Weisz, H. and F. Duchin (2006) Physical and monetary input-output analysis: What makes the difference? *Ecological Economics* 57, 534-541.

Wiedmann, T. and J. Barrett (2013) Policy-relevant applications of environmentally extended MRIO databases – Experiences from the UK. *Economic Systems Research* 25, 143-156.

Wiedmann, T., M. Lenzen and J. Barrett (2009) Companies on the scale - Comparing and benchmarking the sustainability performance of businesses. *Journal of Industrial Ecology* 13, 361-383.

Wiedmann, T., R. Wood, M. Lenzen, J. Minx, D. Guan and J. Barrett (2010) The carbon footprint of the UK - Results from a Multi-Region Input-Output model. *Economic Systems Research* 22, 19-42.

Wiedmann, T.O., G. Chen and J. Barrett (2015a) The concept of city carbon maps: A case study of Melbourne, Australia. *Journal of Industrial Ecology*.

Wiedmann, T.O., H. Schandl, M. Lenzen, D. Moran, S. Suh, J. West and K. Kanemoto (2015b) The material footprint of nations. *Proceedings of the National Academy of Sciences* 112, 6271–6276.

Wier, M. and B. Hasler (1999) Accounting for nitrogen in Denmark - a structural decomposition analysis. *Ecological Economics* 30, 317-331.

Wolff, E. N. (1995) Technological change, capital accumulation, and changing trade patterns over the long term. *Structural Change and Economic Dynamics* 6, 43-70.

Wood, R. and M. Lenzen (2009) Structural path decomposition *Energy Economics* 31, 335-341.

Xia, Yan, Ying Fan, and Cuihong Yang. (2015) "Assessing the impact of foreign content in China's exports on the carbon outsourcing hypothesis." *Applied Energy,* 150, 296-307.

Xiao, Y., C. Benoît-Norris, M. Lenzen, G. Norris and J. Murray (2017) How social footprints of nations can assist in achieving the sustainable development goals. *Ecological Economics* 135, 55-65.

Xiao, Y., M. Lenzen, C. Benoît-Norris, G. Norris and J. Murray (2016) The corruption footprints of nations. *Journal of Industrial Ecology*, in press.

Xu, Y. and E. Dietzenbacher (2014) A structural decomposition analysis of the emissions embodied in trade. *Ecological Economics* 101, 10-20.

Yang, Ling and Michael L. Lahr. (2008). "Labor productivity differences in China, 1987–1997: an interregional decomposition analysis." *Review of Regional Studies*, 38, 319–341.

Yu, Y., K. Hubacek, K. Feng and D. Guan (2010) Assessing regional and global water footprints for the UK. *Ecological Economics* 69, 1140-1147.

Zhang, H. and M.L. Lahr (2014a) Can the carbonizing dragon de domesticated? Insights from a decomposition of energy consumption and intensity in China, 1987–2007. *Economic Systems Research* 26, 119-140.

Zhang, H. and M.L. Lahr (2014b) China's energy consumption change from 1987 to 2007: A multi-regional structural decomposition analysis. *Energy Policy* 67, 682-693.