DATA AND MODEL DOCUMENTATION—002 REV-4

ImpactECON Supply Chain Database

Documentation of data sources and the construction process of IE-SC_v3.0

SUBMITTED BY
ImpactECON, LLC.

Rev 2: GTAP 9 Data Base,
July 2016

Rev 3: GTAP 10 Data Base,
January 2020

Rev4: GTAP 11 Data Base
June 2023

ImpactECON

ImpactECON Supply Chain Database

Documentation of data sources and the construction process of IE-SC_v3.0

Authors: Terrie Walmsley[1] and Peter Minor[2]

Acknowledgments: The construction of this database benefited from the production of an earlier supply chain database funded by the Asian Development Bank.

1 Terrie Walmsley, Director and Senior Economist, ImpactECON, LLC.
2 Peter Minor, Managing Director, ImpactECON, LLC.

Contents

Acronyms

BEC	Broad Economic Classification
CGE	computable general equilibrium
GTAP	Global Trade Analysis Project
HS	Harmonized System
IO	input-output
MRIO	multi-region input-output
UN	United Nations
OECD-TiVA	Organization of Economic Cooperation and Development Trade in Value-add
SITC	Standard International Trade Classification
WCO	World Customs Organization
WIOD	World Input-Output Database

1 Introduction

Analytical tools that trace out how traded goods and services flow between global industries and eventually to final consumers are called supply chain databases.[3] Demand for supply chain databases has increased rapidly in recent years, with several projects developed in response.[4]

The GTAP Data Base, which underlies most of the global computable general equilibrium (CGE) models used for trade, climate change, security, and environmental policy analysis, differs from a well-defined supply chain database. The GTAP Data Base aggregates all imports, by source, at the border and breaks the direct link between supplying countries and individual importing agents (e.g., firms and sectors, households, government and investment). In contrast to the standard GTAP Data Base, the ImpactECON Supply Chain Database traces bilateral trade flows from exporting countries to individual importing agents. To put this another way, in the GTAP Data Base, importing agents know that they are using imports, but they do not know from which country they purchased the import from; this information is lost at the border in the GTAP Data Base. On the other hand, the GTAP Data Base contains more policy instruments, such as taxes, quota rents or government deficits, than the other supply chain or input output datasets and is therefore valued for its broad range in policy analysis.

The ImpactECON Supply Chain Database, the subject of this documentation, adapts the GTAP Data Base to separate import flows by exporting country and importing agent, thereby creating a complete supply chain database from the GTAP Data Base. With this additional information, analyst can now project the impacts of changes in trade flows to particular agents, such as firms. To aid policy analysis the same techniques are also used to differentiate tariffs by exporter and agent. The benefits of adapting the GTAP Data Base are that it offers broad geographical coverage, numerous policy instruments, and has long term support from a community of researchers and policy makers who employ and update the data on an ongoing basis.

---

[3] Within the input-output research community, they are known as multi-region, input-output (MRIO) databases.

[4] Examples of early MRIO databases include EXIOBASE (Tukker, Poliakov, Heijungs, Hawkins, Neuwahl, Rueda-Cantuche, Giljum, Moll, Oosterhaven, and Bouwmeester, 2009), WIOD (Timmer, 2012), OECD-TiVA (OECD, 2012) and EORA (Lenzen, Moran, Kanemoto and Geschke, 2013 and Lenzen, Kanemoto, Moran, and Geschke, 2012). Also using GTAP data, Johnson and Noguera (2012) and Koopman, R., W. Powers, Z. Wang and S. Wei (2010).

In this document, the procedures used to construct the supply chain from the GTAP Data Base are outlined. As will be outlined later in the section on concordances, the classification system used for constructing the Supply Chain Database is a guideline produced by international institutions. As a guideline, the classification system recognizes the potential for data improvement for individual industries or countries. The resulting ImpactECON Supply Chain Database, likewise, is open to improvement as better data on the use of imports by agents in each country becomes available. ImpactECON welcomes comments or suggestions for improved data classification.

Versions: This document accompanies all versions related to the ImpactECON construction process identified by IE-SC_v3.0. Each IESC database has a header MREL[5] that contains information (e.g., IE-SC_v3.0_R11.0_2017_Mar2023) to identify the IE construction version, in this case IE-SC_v3.0, and the GTAP Data Base to which it relates, R11.0_2017_Mar2023.

The first ImpactECON Supply Chain Database, IE-SC_v1.0_R8.01_2007_12June2012, was not released publicly, although it was used in Walmsley and Minor (2015). It was based on the construction procedure documented in Walmsley, Hertel, and Hummels (2014).

IE-SC_v2.0 and IE-SC_v3.0 contain multiple updates to the underlying data, the BEC concordance and the methodology used to construct the database. The IE-SC_v2.0 methodology has then been applied to versions 9, 9.2 and 10 of the GTAP Data Base. For version 9 and 9.2, new trade data by agent and differential tariff rates by agent corresponding to 2011 were incorporated. For version 10, these trade data by agent and differential tariff rates by agent have been updated to 2014. The IE-SC_v3.0 methodology has then been applied to version 11 of the GTAP Data Base. For version 1, new trade data by agent and differential tariff rates by agent corresponding to 2017 were incorporated and the BEC concordance updated to version 5.

[5] We also include the original GTAP identifier, DREL. Note that the information contained in DREL MUST match the GTAP related information contained in the ImpactECON identifier, MREL.

2 The construction process

2.1 Data Sources

A list of the data sources used in the construction of IE-SC_v3.0_R10_2017_Mar2023 include:

1. The GTAP Data Base. In this case R11_2017_Mary 2023 documented in Aguiar, Chepeliev, Corong, & van der Mensbrugghe (2023);
2. Classification by Broad Economic Categories (BEC) R5 (United Nations Statistics Division, New York)[6];
3. Trade data by HS six-digit (HS6) commodity codes, source and destination (MAcMap HS6 a joint project between the ITC-UNCTAD-WTO and CEPII);
4. Tariff data by HS six-digit commodity, source and destination (MAcMap HS6 a joint project between the ITC-UNCTAD-WTO and CEPII).

2.2 Overview of the Process

The standard GTAP Data Base contains several data elements related to imports. If we ignore alternative price valuations for the time being and concentrate on those valued at market prices[7], there are four relevant data elements:

1. $VIFM_{i,j,r}$: value of imports of commodity i purchased by firm j (including investment) in region r at market prices
2. $VIPM_{i,r}$: value of imports of commodity i purchased by "private" households in region r at market prices
3. $VIGM_{i,r}$: value of imports of commodity i purchased by governments in region r at market prices
4. $VIMS_{i,s,r}$: value of imports of commodity i supplied by region s to region r at market prices

Since all these imports are valued at market prices and the supply of imports from all sources ($VIMS_{i,s,r}$) should equal demand for imports from all agents, where our agents include: the 57 GTAP sectors or firm demand ($VIFM_{i,j,r}$), private households ($VIPM_{i,r}$), government ($VIGM_{i,r}$) and investment ($VIFM_{i,cgds,r}$)). We therefore have the following relationship:

$$\sum_s VIMS_{i,s,r} = \sum_j [VIFM_{i,j,r}] + VIPM_{i,r} + VIGM_{i,r} \qquad (1)$$

Our aim in converting the GTAP Data Base into a supply chain database is to replace these four headers with the following three headers that provide information on the source of imports by agent:

---

[6] BEC Revision 5 has been under construction by the UN since 2016 and was released to the public, in the form of concordances, in 2019.The IESC for version 11 of the GTAP database utilizes the BEC Revision 5 concordances, in contrast to prior IESC databases, which utilized the BEC Revision 4 concordances.

[7] Market prices are tariff and transport inclusive sometimes referenced as "landed duty paid."

1. $VIFMS_{i,j,s,r}$: value of imports of commodity i, supplied by region s, and purchased by firms in sector j (including investment) in region r at market prices;
2. $VIPMS_{i,s,r}$: value of imports of commodity i, supplied by region s, and purchased by private households in region r at market prices;
3. $VIGMS_{i,s,r}$: value of imports of commodity i, supplied by region s, and purchased by governments in region r at market prices.

In order to do this, information defining the exporter by importing agent is required. As a first approximation one might assume that all agents purchase imports from the same sources and hence:

$$\frac{\mathrm{VIFMS}_{i,\mathrm{j},\mathrm{s},\mathrm{r}}}{\sum_s VIFMS_{i,\mathrm{j},\mathrm{s},\mathrm{r}}} = \frac{\mathrm{VIPMS}_{i,s,\mathrm{r}}}{\sum_s VIPMS_{i,s,r}} = \frac{\mathrm{VIGMS}_{i,s,\mathrm{r}}}{\sum_s VIGMS_{i,s,r}} = \frac{\mathrm{VIFMS}_{i,\mathrm{cgds},s,\mathrm{r}}}{\sum_s VIFMS_{i,cgds,s,r}} = \frac{\mathrm{VIMS}_{i,s,r}}{\sum_s VIMS_{i,s,\mathrm{r}}} \qquad (2)$$

This is known as the proportionality method and it is used in cases where no better information can be obtained—however it is based on strong assumptions.

A better method is to use the Broad Economic Categories (BEC). The BEC classify each HS6 commodity into three or four broad economic categories—intermediate, consumer, and investment goods—depending on which agent is considered to be the main purchaser of the good. Since different countries export and import different commodities as defined by the HS6 classification, it is likely that goods categorized as intermediates will be exported by different countries. For instance, concentrated orange juice packed in drums (HS6 code Chapter 20—2009.11) is believed to be purchased by intermediate food processors while fresh orange juice not concentrated (HS6 code Chapter 20—2009.12) is thought to be imported by final consumers (households and government). Once combined with the trade data we might see that concentrated orange juices come mostly from Brazil, while fresh orange juice is mostly imported from South Africa; and hence we can infer that orange juice imported for intermediate use is most likely from Brazil and orange juice imported for final consumption is from South Africa. When these HS6 trade data are aggregated to the 57 GTAP commodities by agent we obtain the following three shares for iNtermediates ($\mathrm{VINMS}_{i,s,\mathrm{r}}$), Investment ($\mathrm{VIIMS}_{i,s,\mathrm{r}}$) and finaL consumption goods ($\mathrm{VILMS}_{\mathrm{i},s,r}$) respectively:

$$\frac{\mathrm{VINMS}_{i,s,\mathrm{r}}}{\sum_s VINMS_{i,\mathrm{s},\mathrm{r}}}, \frac{\mathrm{VIIMS}_{i,s,\mathrm{r}}}{\sum_s VIIMS_{i,\mathrm{s},\mathrm{r}}} \text{ and } \frac{\mathrm{VILMS}_{\mathrm{i},s,r}}{\sum_s VILMS_{i,s,r}} \qquad (3)$$

These distinctions made at the HS6 commodity level leads to different sourcing shares (patterns) by agent.

The sourcing shares based on the BEC represent the first step to creating the supply chain database. The next step is to rebalance the sourcing shares in order to ensure that the original balance in the GTAP Data Base between supply and demand (equation (1)) is maintained.

We also maintain the original components of equation (1), imports by source and destination ($VIMS_{i,s,r}$), as well as imports by agent – firm demand ($VIFM_{i,j,r}$), private households ($VIPM_{i,r}$), government ($VIGM_{i,r}$) and investment ($VIFM_{i,cgds,r}$). In doing so, we are utilizing the best

information available on import use by source, destination and agent from two sources, which do not always agree. To understand the value of each database and the information it contributes, we briefly review how each dataset is constructed and how they are leveraged for the best information.

Imports by agent ($VIPM_{i,r}$, $VIGM_{i,r}$, $VIFM_{i,cgds,r}$) in the GTAP Data Base are constructed based on the contributed country input-output (IO) tables. We recognize that many IO tables produced by statistical offices around the world do not separate domestic and imported use on a regular basis; hence this aspect of the contributed IO tables is likely to have been estimated and therefore is a potential source of error. That said, our analysis of the GTAP Data Base revealed that most IO tables did not report the same import share across all uses, leading us to believe that there is valuable information in the GTAP data. BEC on the other hand, even though it is defined at the detailed HS-6 level, can be a coarse rule. Table 2-1 illustrates four GTAP commodities and contrasts between the classification systems: petroleum (OIL), paper products (PPP), wearing apparel (WAP) and other grains then wheat (GRO). The first two products, petroleum (OIL) and paper products (PPP), illustrate that the GTAP data derived from the IO table contributions and imports classified by BEC can provide very similar results. In cases of the third (wearing apparel) and fourth commodities (grains), significant differences in agent use classifications exist between the GTAP data and the BEC. In the case of wearing apparel (WAP), the GTAP IO data suggest approximately 16.5 percent of wearing apparel are intermediate goods—hospital gowns and industrial uniforms are notable categories of intermediate uses of wearing apparel. In contrast, the BEC indicates less than one percent of wearing apparel products are intended for intermediate use. Further investigation into the BEC categories shows that only six HS-6 products, primarily unfinished furs and hats, are classified for firm use. The HS-6 classification system does not distinguish hospital gowns or industrial work cloths; however, national tariff schedules do provide this information. In this case, the GTAP IO data provide additional information not contained in the BEC, and our algorithms allocate 16.5 percent of wearing apparel imports to firm use, in contrast to the BEC, which indicate less than one percent. The fourth product, other grains then wheat, which includes corn, rye, oats, barley, and other grains, the BEC indicates 100 percent of imports of these products are used by firms, which we believe is unlikely. In contrast the GTAP IO based data suggest approximately 24 percent of other grains imported are purchased by final consumers. Once again, the GTAP IO data is of help here and imports are more variegated in the ImpactECON Supply Chain Database as a result of employing the GTAP IO data.

Table 2-1: GTAP IO data compared to BEC classification of imports (percent of commodity imports)

	GTAP (GTAP 2014 trade data)			BEC (MacMap 2014 trade)		
GTAP sector	Capital	Interme diate	Final Consumer	Capital	Interme diate	Final Consumer
Crude petroleum (OIL)	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
Paper and paper product (PPP)	1.5%	89.7%	8.5%	0.0%	78.2%	21.8%
Wearing apparel (WAP)	0.6%	16.5%	82.8%	0.0%	0.2%	99.8%
Grains other than wheat (GRO)	0.7%	75%	24.2%	0.0%	100.0%	0.0%

Source: ImpactECON analysis of GTAP V10 and MacMap 2014 databases.

One broad implication of using the GTAP IO data in combination with the BEC data, are that there are generally less extreme allocations of imports by agent than is implied by the BEC classification. In general, we find the BEC classifies most primary and raw materials (agricultural and extraction) as entirely intermediate goods, while GTAP IO data contain more variegated information.

In the resulting database the bilateral sourcing shares differ between agents—firms, final consumers and investment—although not between sectors (firms) or final consumer categories (households and government) that are explicit in the GTAP Data Base. This is due to the fact that the BEC concordance does not provide sufficient detail to determine if a good was sold to households or government or to specific sectors. To put this another way, the import sourcing shares for a given intermediate good, such as "OME-Other Machinery and Equipment", does not vary between the 65 GTAP sectors. However, the sourcing shares for OME does vary between sectors and final consumers. Hence:

$$\frac{\mathrm{VIFMS}_{i,\mathrm{j},\mathrm{s},\mathrm{r}}}{\sum_s VIFMS_{i,\mathrm{j},\mathrm{s},\mathrm{r}}} = \frac{\mathrm{VIFMS}_{i,\mathrm{k},\mathrm{s},\mathrm{r}}}{\sum_s VIFMS_{i,\mathrm{k},\mathrm{s},\mathrm{r}}} \neq \frac{\mathrm{VIFMS}_{i,\mathrm{cgds},\mathrm{s},\mathrm{r}}}{\sum_s VIFMS_{i,\mathrm{cgds},\mathrm{s},\mathrm{r}}} \neq \frac{\mathrm{VIPMS}_{\mathrm{i},s,r}}{\sum_s VIPMS_{i,s,r}} = \frac{\mathrm{VIGMS}_{\mathrm{i},s,r}}{\sum_s VIGMS_{i,s,r}} \quad (3)$$

Once we have the market value of imports by commodity, agent, source and destination the next step is to calculate the sales tax inclusive values ($VIFA_{i,j,r}$, $VIPA_{i,r}$, $VIGA_{i,r}$ and $VIFA_{i,cgds,r}$). We assume that sales taxes by agent and source are applied at the same rate as sales taxes applied on imports purchased by that agent in general, regardless of the source of the commodity. This assumption seems reasonable since sales taxes are rarely applied differentially by source country. For instance, sales tax paid on juice purchased directly by a private consumer may differ from sales tax applied on a juice purchased as part of a meal at a

restaurant, but rarely does a consumer have to pay higher sales tax on a South African juice than on Brazilian juice simply because it is Brazilian (of course they may have a different tax due differences in sugar content, but this is not due to the juice's origin). The same cannot be said for tariffs, to which we now turn our attention.

Finally, we must also calculate the value of imports by commodity, agent, source and destination at world prices; that is before import duties are paid. Since imports of aggregated GTAP commodities by different agents consist of different HS6 goods it is reasonable to assume that tariffs may differ by agent. For instance, cartons of fresh juice may be subject to very different tariffs than juice purchased in a bulk concentrate hence leading to very different tariffs applied on final consumers and firms purchases of juice.[8] The differential tariffs found using the BEC concordance represent our initial estimates of the tariff rates by broad economic category. In order to apply these to the various GTAP agents, we make use of the newly balanced trade data and the original BEC trade data to determine the average tariff paid by the agents.[9] The importance of taking the trade data into account is most evident if you consider the following example. Imagine that barrels of juice concentrate purchased by firms have low tariff rates, while cartons and bottles sold to final consumers are subject to higher rates. If our input-output data indicate that firms' purchases of juice are greater than the amount of juice purchased in barrels, we must conclude that firms buy both barrels and cartons (not surprising really). The tariff applied to juice purchased by firms is therefore a weighted average of the two types. It will be lower than the tariff paid by final consumers, who only buy cartons of juice, although it will be higher than the tariff applied to barrels of juice.

In the next stage the tariff rates are adjusted to ensure total tariff revenue in the GTAP Data Base remains unchanged. We include a complementarity to ensure that the tariff rate does not fall below zero or rise above the maximum tariff rate of any good (at the HS6 level) contained within the GTAP category. As in equation (3) tariffs differ across the broad economic agents, but are the same within the broad categories:

$$TFMS_{i,j,s,r} = TFMS_{i,k,s,r}$$

$$\neq TFMS_{i,cgds,s,r}$$

$$\neq TPMS_{i,s,r} = TGMS_{i,s,r} \qquad (3)$$

The supply chain database is then assembled.

---

[8] Abstracting for the moment from the fact that juice is classified in the aggregate GTAP sector which includes other beverages and tobacco products.

[9] To do this we use the trade data by BEC category combined with GTAP trade data by agent to construct a trade matrix of trade by commodity, BEC category, agent, source, and destination that is consistent with the GTAP trade data. This matrix is supplied as part of the IESC database in a file named matrix.har. This is discussed further below in section 2.3.

2.3 matrix.har

In order to construct tariffs paid by agent, a trade matrix must be produced that shows trade by commodity, BEC category, agent, source, and destination that is consistent with the GTAP trade data by commodity, source and destination and by commodity, agent and destination. This matrix is produced assuming that agents purchase primarily from the BEC category that best matches their purchases and then from the remaining categories. Two matrixes are provided, one consistent with the values of VIWS (trade at c.i.f prices) and VIMS (imports at market prices) in the GTAP Data Base.

This file also contains two sets of tariff data by commodity, BEC category, agent[10], source and destination. Data at header "GTAR" is consistent with the tariff data contained in the GTAP database and data at header "0TAR" is obtained from the HS six-digit commodity, source and destination supplied by MAcMap HS6 (a joint project between the ITC-UNCTAD-WTO and CEPII).[11]

These matrixes allow users to construct tariff scenarios by agent or BEC category using HS-6 level tariff data. Indeed, these matrixes are essential for taking account of sensitive products, which are likely to impact agents differentially depending on whether the sensitive product is considered to be a final, intermediate or capital good.

---

[10] Note that tariffs do not differ by agent, only by BEC category at this level. Differences across agents arise when tariffs are aggregated over BEC categories using the trade data.

[11] Note that the tariffs contained in matrix.har are not fully consistent with the GTAP tariffs, since GTAP are not fully consistent with the MAcMap data. While the differences are usually small, some differences can arise. Those working with HS-6 data often use the Altertax facility, developed by Malcom (1998) to adjust the GTAP tariffs to make them consistent with the MAcMap tariffs.

3 A closer look at the BEC concordances

3.1 The BEC concordances: a guideline for national use

The BEC was developed by the United Nations in response to a growing need in the international community for broad classification of traded commodities based on their end-uses: capital, intermediate, and consumption goods. The first version of the BEC was published in 1971 and several revisions to the system have been published. The latest revision, Revision 5, is used in constructing the GTAP V11 ImpactECON Supply Chain Database.

The BEC is not a standard classification in the traditional sense used in the international community, and BEC documentation repeatedly makes reference to this point. In a standard classification, countries recognize the definition as authority, as is the case with signatories of the World Customs Organization (WCO) Harmonized System classification, or the United Nations (UN) Standard International Trade Classification (SITC). In contrast to standard classifications, the BEC is provided as a "guideline" for national use. Nevertheless, the UN has recognized the growing need to refine the BEC over time and has commissioned the construction of tables which provide for the correlation of HS coding into BEC classifications, while recognizing the end product is a work in progress.

As a guideline for national use, the UN recognizes that individual countries may wish to adjust the classification to suit their particular situation. For example, in most cases, internationally traded fresh fruit and vegetables are classified for final consumption in the BEC. Likewise, whole grains and flour are classified for intermediate use, in contrast to for final consumption. An individual country may find that its own particular situation does not fit this broad classification, and they may choose to define, based on their individual situation, certain types of fresh fruit, for example, as mainly for intermediate use, in contrast to the definition provided in the BEC.

3.2 Goods without BEC classification

Not all goods traded internationally have a BEC classification code. As noted above, the BEC relies on a definition of main "end-use." In certain cases, such as with passenger cars and motor vehicle spirts (petroleum), an unambiguous end-use is not evident. For example, in the case of passenger cars, the BEC does not provide a classification into intermediate or consumer goods, since these goods are used extensively by both firms and consumers. In these cases, the BEC does not provide a classification. In cases where the BEC does not provide a classification, we calculate the share of imports, by sector, and end-use (agents) as represented in the GTAP Data Base. For example, if 20 percent of imported "MVH-motor vehicles" are purchased by firms

and 80 percent are purchased by final consumers in a particular country, imports of passenger cars, without a BEC classification, are allocated with these proportions, regardless of source.

The BEC classification also includes a category "8-Government, military and other." Goods in this category include military equipment, postal parcels and monetary instruments (including coins and currency). These goods have been classified in the Supply Chain Database as "Government" purchases; but are not yet implemented in the published version.

4 Future Directions

The ImpactECON Supply Chain Database is constructed based on the UN BEC concordances. As was noted earlier, the BEC concordances are "national guidelines" for the classification of commodities by end-use. As a guideline, the BEC recognizes that the classification is a starting point for improved classification. The ImpactECON Supply Chain Database, likewise, should be viewed as a work in progress. Since there are over 200 countries and over 5,000 HS6 commodities in the international trade system, it would be reasonable to expect that the ImpactECON Supply Chain Database should reflect the continuous development and refinement of knowledge on the supply and use of internationally traded commodities. Alternative data sources on outward processing arrangements and national tariff schedules, for example, could provide a useful source of improved classification of goods as "intermediate" or "consumer" goods[12].

National sources of data may provide more information on the end use of specific commodities. In these cases, the national data should override the BEC guidelines for improved classification. In other cases, it may be natural to redefine conventions in the BEC, depending on geographic or economic development levels. For example, the classification of grain and flour into intermediate goods for developed countries may be reasonable. In contrast, developing countries may have different norms in the use of these commodities.

Those interested in the ImpactECON supply chain model that accompanies this supply chain database are referred to Walmsley and Minor (2016).

[12] This can be seen as particularly significant when it is known that much of the fabric shipped in outward processing arrangements are actually classified as "apparel" since the fabric is cut into pieces before being shipped and is classified as "apparel"—a final good in the BEC. Simple information such as this could improve on the BEC guidelines and the associated supply chain relationships.

Bibliography

Aguiar, A., Chepeliev, M., Corong, E., & van der Mensbrugghe, D. (2023). The Global Trade Analysis Project (GTAP) Data Base: Version 11. *Journal of Global Economic Analysis*, *7*(2). https://doi.org/10.21642/JGEA.070201AF (Original work published December 19, 2022)Johnson, R. C. and G. Noguera (2012), "Accounting for Intermediates: Production Sharing and Trade in Value Added." *Journal of International Economics*, 86 (2): 224-236.

Koopman, R., W. Powers, Z. Wang and S. Wei (2010), "Give Credit where credit is due: Tracing the Value-added in Global Production Chains", NBER Working Paper No. 16426, http://www.nber.org/papers/w16426

Lenzen, M., K. Kanemoto, D. Moran, and A. Geschke. 2012. Mapping the structure of the world economy. *Environmental Science & Technology* 46(15): 8374–8381.

Lenzen, M., D. Moran, K. Kanemoto and A. Geschke (2013), "Building Eora: A Global Multi-region Input-output Database at high country and sectoral resolution", *Economic Systems Research*, 25(1): 20-49.

Malcom, G., 1998, "Adjusting Tax Rates in the GTAP Data Base", GTAP Technical Paper No. 12, Center for Global Trade Analysis, West Lafayette, IN, USA

OECD (2012), *Measuring Trade in Value-added; An OECD-WTO Joint initiative*. Paris, France, OECD.

Timmer, M. P., (2012), "The World Input-Output Database (WIOD): Contents, Sources and Methods", WIOD Working Paper Nr. 10

Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T., Neuwahl, F., Rueda-Cantuche, J., Giljum, S., Moll, S., Oosterhaven, J. & Bouwmeester, M. (2009), "Towards a global multi-regional environmentally extended input-output database." *Ecological Economics*, 68 (7): 1929-1937.

Walmsley, T. L., T. W. Hertel, and D. Hummels (2014). "Developing a GTAP-Based Multi-Region, Input-Output Framework for Supply Chain Analysis". In Ferrarini, B., and D. Hummels, Asia and Global Production Networks—Implications for Trade, Incomes and Economic Vulnerability, Asian Development Bank, Edward Elgar.

http://www.adb.org/publications/asia-and-global-production-networks-implications-trade-incomes-and-economic-vulnerability

Walmsley T. L., and P. Minor, (2015). "Willingness to Pay in CGE Models", ImpactECON Working Paper No. 04, ImpactECON: Boulder, CO, USA

Walmsley T. L., and P. Minor, (2016). "ImpactECON Supply Chain Model: Documentation of model changes", ImpactECON Working Paper No.6, ImpactECON: Boulder, CO, USA