

## On-line Appendix

In this appendix, we outline our input-output decomposition method in a more formal way, and briefly discuss how two major challenges in the construction of the World Input-Output Database construction have been dealt with.

### **The input-output decomposition method**

Our decomposition method is a multi-country extension of the approach outlined by Leontief (1936). Leontief started from the fundamental input-output identity which states that all products produced must be either consumed or used as intermediate input in production. This is written as  $\mathbf{q} = \mathbf{B}\mathbf{q} + \mathbf{c}$ , in which  $\mathbf{q}$  denotes a vector of industry-level gross outputs,  $\mathbf{c}$  is a vector with final consumption levels for the outputs of each of the industries and  $\mathbf{B}$  stands for a matrix with intermediate input coefficients. These coefficients describe how much intermediates are needed to produce a unit of output of a given product.  $\mathbf{B}\mathbf{q}$  is then the total amount of intermediates used. The identity can be rewritten as  $\mathbf{q} = (\mathbf{I} - \mathbf{B})^{-1}\mathbf{c}$ , in which  $\mathbf{I}$  represents an identity matrix.  $(\mathbf{I} - \mathbf{B})^{-1}$  is famously known as the Leontief inverse. It gives the gross output values of all products that are generated in all stages of the production process of one unit of a specific final product. To see this, let  $\mathbf{z}$  be a column vector of which the first element represents the global consumption of *i*Pods produced in China, and all other elements are zero. Then  $\mathbf{B}\mathbf{z}$  is the vector of intermediate inputs, both Chinese and foreign, needed to assemble the *i*Pods in China, such as the hard-disk drive, battery and processors. But these intermediates need to be produced as well and  $\mathbf{B}^2\mathbf{z}$  indicates the intermediate inputs directly needed to produce  $\mathbf{B}\mathbf{z}$ . This continues until the mining and drilling of basic materials such as metal ore, sand and oil required to start the production process. Summing up across all stages, one derives the gross outputs generated in the production of *i*Pods by  $(\mathbf{I} - \mathbf{B})^{-1}\mathbf{z}$ , since the summation across all rounds converges to  $(\mathbf{I} - \mathbf{B})^{-1}\mathbf{z}$  under empirically mild conditions (see Miller and Blair, 2009, for a good starting point for more information on input-output analysis).

To find the value added by factors we additionally need factor inputs per unit of gross output represented in a diagonal matrix  $\mathbf{F}$ . An element in this matrix indicates the value added by a particular production factor as a share of gross output. These are factor-, country- and industry-specific, one element contains the value added per dollar of output by labor in the Chinese electronics industry, for example. To find the value added by all factors that are directly and indirectly involved in the production of a particular final good, we multiply  $\mathbf{F}$  by the total gross output value in all stages of production given above such that  $\mathbf{k} = \mathbf{F}(\mathbf{I} - \mathbf{B})^{-1}\mathbf{z}$ .

A typical element in  $\mathbf{k}$  indicates the value added in the production of the first final good by the particular production factor employed in country  $i$  and industry  $j$ . By the logic of Leontief's insight, the sum over value added by all factors in all countries that are directly and indirectly involved in the production of this good will equal the output value of that product. By repeating this procedure for all final goods and production factors, we have completed our

decomposition of final output into the value added by various production factors around the world.

### **Two Challenges in the Construction of the World Input-Output Database**

To empirically apply the decomposition method outlined above, we rely on the World Input-Output Database. This database is freely available at [www.wiod.org](http://www.wiod.org) has been specifically constructed for this type of analyses. The tables have been constructed by combining national input-output tables with bilateral international trade data, following the conventions of the System of National Accounts. Timmer et al. (2014) provides an overview and technical details are given in Dietzenbacher et al. (2013).

The first major challenge in the construction of the world input-output tables was to have tables that are consistent over time. National input-output tables are only available for particular benchmark years that are infrequent, unevenly spread over time, and asynchronous across countries. Moreover, in contrast to the more familiar national accounts statistics, such input-output tables are often not revised when new information becomes available, or only revised with a considerable lag. Time consistency has been achieved through a procedure that imputes coefficients subject to hard data constraints from national accounts statistics, using a constrained least square method akin to the well-known bi-proportional proposed by Richard Stone (1961). The result of this imputation is that the input-output tables exactly match the most recent data from national accounts statistics on household consumption, investment government consumption, total exports and imports, and gross output and intermediate inputs by detailed industry. Value added is defined in the standard way as gross output (at basic prices) minus the cost of intermediate goods and services (at purchasers' prices).

The world input-output tables are based on imputation of supply- and use-tables, rather than input-output tables. The supply-and-use tables provide a more natural starting point than input-output tables, which are typically derived from the underlying supply- and use-tables with additional assumptions. Moreover, supply and use-tables can be easily combined with trade statistics that are product-based and employment statistics that are industry-based. The national supply- and use-tables have 35 industries and 59 product groups. The 35 industries cover the overall economy and are mostly at the 2-digit NACE rev. 1 level or groups there from. Dietzenbacher et al. (2013) discuss the technical details.

The second major challenge was the allocation of imports to a use category and the disaggregation by country and industry of origin. Typically, researchers rely on the so-called "import proportionality assumption," applying a product's economy-wide import share for all the uses to which the product is put (for example, Johnson and Noguera 2012). However, this assumption can be misleading as import shares vary significantly across various uses (Feenstra and Jensen 2012). To improve upon this, the detailed descriptions for about 5,000 products (at the six-digit level in the UN COMTRADE database) were used to allocate imports to three use categories: intermediate use, final consumption use, or investment use: in effect, refining the well-known "broad economic classification" (BEC) from the United Nations. This was

combined with the detailed HS-6 bilateral trade data to breakdown a country's import of each of the 59 products into the country-of-origin. In addition, data on bilateral trade in services, which in contrast to data on goods is not readily available, has been collected, integrating various international data sources. This includes payments for various kinds of business services, royalties and license fees.

As is well-known, data on services trade has not been collected with the same level of detail and accuracy as data on goods trade and there is still much to be improved in particular in the coverage of intra-firm deliveries (Francois and Hoekman 2010). However, this does not mean that the values of these services are excluded in our decomposition. On the contrary, as the decomposition of the products' value is complete, it is accounted for, even if the location of the value added might be harder to trace. Take the example of a typical US manufacturer of trousers that does not have any production capacity in the US, but basically only governs foreign production and maintains brand and design at home (so called "fables manufacturers"). The value of the trouser includes the compensation for brand and design and this will show up in the value added by capital in the US clothing industry.

## References

- Dietzenbacher, Erik, Bart Los, Robert Stehrer, Marcel P. Timmer, and Gaaitzen J. de Vries.** 2013. "The Construction of World Input–Output Tables in the WIOD Project." *Economic Systems Research* 25(1): 71-98.
- Feenstra, Robert C., and J. Bradford Jensen.** 2012. "Evaluating Estimates of Materials Offshoring from U.S. Manufacturing." *Economics Letters*, 117(1): 170–173.
- Francois, Joseph, and Bernard Hoekman.** 2010. "Services Trade and Policy." *Journal of Economic Literature* 48(3):642-692.
- Johnson, Robert C., and Guillermo Noguera.** 2012. "Accounting for Intermediates: Production Sharing and Trade in Value Added." *Journal of International Economics* 86(2): 224-236.
- Leontief, Wassily.** 1936. "Quantitative Input-Output Relations in the Economic System of the United States." *Review of Economics and Statistics* 18(3): 105-125.
- Miller, Ronald E., and Peter D. Blair.** 2009. "Input-output Analysis: Foundations and Extensions." Cambridge, Cambridge University Press.
- Stone, Richard.** 1961. *Input–Output and National Accounts*, Paris: Organization for European Economic Cooperation.
- Timmer, Marcel P., Erik Dietzenbacher, Bart Los, Robert Stehrer and Gaaitzen J. de Vries.** 2014. "The World Input-Output Database (WIOD): Contents, Concepts and Applications", GGDC Research Memorandum No. 144, Groningen.

**Appendix Table 1 Value added share of countries in all global value chains of manufactures**

	1995	2008	2008 minus 1995
United States	19.9	15.8	-4.1
Japan	17.5	7.8	-9.7
Germany	9.4	7.6	-1.7
France	4.4	3.8	-0.6
United Kingdom	3.8	3.0	-0.9
Italy	4.4	4.1	-0.3
Spain	1.9	2.0	0.0
Canada	1.9	2.2	0.3
Australia	1.0	1.3	0.3
South Korea	2.1	1.8	-0.3
Netherlands	1.4	1.4	-0.1
Other ten high-income	5.9	5.3	-0.6
<b>Total all high-income</b>	<b>73.8</b>	<b>56.0</b>	<b>-17.8</b>
China	4.2	12.8	8.6
Russian Federation	1.2	2.8	1.6
Brazil	2.5	3.0	0.6
India	1.7	2.6	0.9
Mexico	1.5	2.4	0.9
Turkey	1.1	1.4	0.3
Indonesia	1.3	1.3	0.0
Rest of world	12.7	17.5	4.9
<b>World minus all high-income</b>	<b>26.2</b>	<b>44.0</b>	<b>17.8</b>
<b>World</b>	<b>100.0</b>	<b>100.0</b>	<b>0.0</b>

*Notes:* Shares of country in world value added (per cent), based on all global value chains of manufactures.

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.

**Appendix Table 2 Number of workers in global value chains of manufactures by sector of employment.**

	Manufactures GVC workers as (%) share of all workers in the economy		Manufactures GVC workers in 2008 (in thousands) employed in				Change in manufactures GVC workers between 1995 and 2008 (in thousands) employed in			
			Agriculture	Manufacturing	Services	All sectors	Agriculture	Manufacturing	Services	All sectors
	1995	2008								
United States	16.0	11.1	1,143	8,837	6,892	16,872	-331	-3,144	-1,138	-4,612
Japan	22.6	19.4	1,298	6,491	4,417	12,207	-794	-2,225	148	-2,871
Germany	26.8	26.4	400	5,481	4,766	10,647	-161	-666	1,388	561
France	22.0	18.7	303	2,195	2,355	4,853	-96	-423	368	-151
United Kingdom	20.1	12.6	115	1,946	1,931	3,992	-128	-1,148	-347	-1,624
Italy	29.1	25.5	333	3,553	2,559	6,444	-192	-234	517	91
Spain	23.2	17.5	271	1,827	1,494	3,592	-97	185	353	440
Canada	20.8	16.0	157	1,138	1,482	2,777	-102	-136	193	-45
Australia	18.2	14.5	165	641	855	1,661	-48	3	196	150
South Korea	29.7	22.8	655	2,646	2,077	5,378	-468	-735	524	-679
Netherlands	22.8	19.0	89	643	929	1,661	-42	-87	158	29
China	31.7	33.3	121,342	87,568	49,468	258,378	9,963	20,508	11,965	42,436
Russian Federation	24.7	21.9	4,259	6,749	6,228	17,237	-1,403	-2,120	2,198	-1,325
Brazil	29.6	28.7	8,347	9,490	9,823	27,660	-705	2,450	4,118	5,863
India	27.9	27.3	57,926	41,933	26,483	126,343	2,118	10,896	7,025	20,039
Mexico	30.3	24.4	2,817	6,128	3,205	12,150	-400	1,403	1,121	2,124
Turkey	27.1	30.4	1,778	3,115	1,554	6,446	-341	620	584	863
Indonesia	32.1	25.6	13,921	7,427	5,725	27,073	-1,899	-425	1,380	-944

*Notes:* Number of workers (including employees and self-employed) involved in global production of final manufactures.

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.