Chapter 2
Methodology

2.1 Introduction to Input Output Analysis

In late November 2015, Turkish militants shot down a Russian fighter jet when it was fighting Islamic State militants in Syria on the basis of violating Turkish airspace, according to Turkish authorities. Vladimir Putin, president of Russia, took a series of political and economic actions against Turkey. One of those actions was to stop buying Turkish vegetables, which forced the government to look for other markets. This had a dramatic effect on the Turkish agriculture sector, which as a direct consequence had to lay off some workers. The transportation sector was also affected as it transported commodities from farms to ports. Packaging of those products was similarly affected. Meanwhile, other markets, for example Morocco and Tunisia would have gained from that action because to satisfy its demand, Russia had to find alternative trading partners. The number of those employed in the Moroccan agriculture sector would have increased, as well as in those employed in transportation and other sectors. Increasing exports may encourage Morocco to expand or build new ports to facilitate the exporting process, which in turn would indirectly benefit the manufacturing and construction sectors. The question has to be asked, how can we evaluate and measure the spillover effects of Putin's actions, in particular those related to economic sanctions?

One of the most robust techniques that is used to measure the impact of international trade on economic indicators is Multi-Regional Input-Output (MRIO) analysis. The root of this technique dates back to the 1930s when Wassily Leontief developed his theory about input-output techniques. The first input-output table created was for the US economy in 1936 (Leontief 1936). In his research he showed how changes in one economic sector could have an influence on other sectors in the US economy. For this pioneering work, he won the Nobel Memorial Prize in Economic Sciences in 1973. Input-output tables show the flow of goods and services among sectors in an economy. It consists of three blocks; $N \times N$ intermediate matrix $\mathbf{T}$, $N \times M$ final demand $\mathbf{y}$ and $K \times N$ primary or value added $\mathbf{v}$ block (Fig. 2.1). The intermediate block holds

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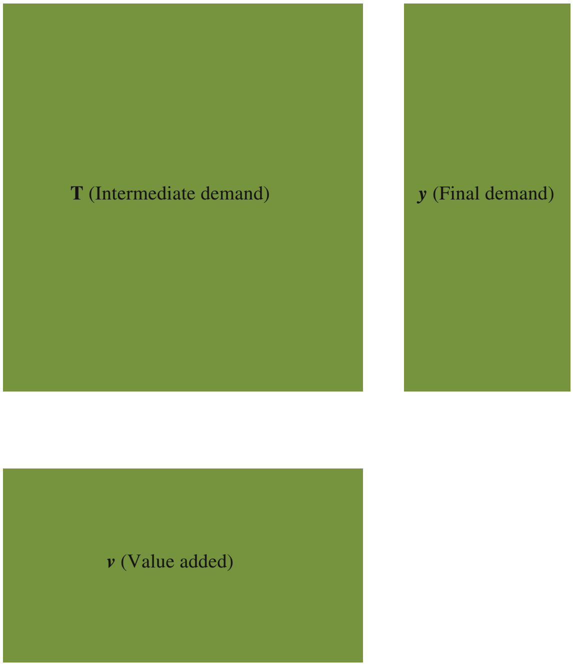
Fig. 2.1 Input output structure



monetary transactions from one sector to another within an economy. Final demand contains two main sub-blocks or categories: (1) *Gross National Expenditure* which includes households and government expenditure, gross fixed capital expenditure and change in inventories and (2) *Exports*. The value added or primary input block also contains two main sub-blocks or categories: (1) *Gross Domestic Products* which includes wages, gross operation surplus, taxes and subsidies (2) *Imports*.

The amount of sector i needed to produce one unit of sector j is called the technical coefficient aij. Thus, the technical coefficient matrix **A** that holds the entire interconnection among sectors in an economy shows the production recipes of those sectors, where $\mathbf{A} = (a_{ij}) = a_{ij}/x_j$, and x_j is the total output of sector j.

2.2 Satellite Account

The satellite account is an account that can be used to link physical data (e.g. tonnes) with monetary data that exist in the input output table. This account gives us more information about a country's national account data. While the IO table shows the interactions between sectors, households, government, and exports and imports, satellite accounts reveal information about the physical data of, for instance, the volume of emissions emitted from each sector of an economy. Satellite account units can be in tonnes, cubic meter, Full-Time Equivalent (FTE), etc. From recent years and on a regular basis, most developed and some developing countries have published data about satellite indicators.

Fig. 2.2 Sample of a concordance matrix

New classification

Raw data						
	1	0	0	0	0	0
	0	1	0	0	1	0
	0	0	1	1	0	0
	0	0	0	1	0	0
	0	0	0	0	1	1

The satellite account is a $1 \times N$ vector and has the same classification as **T** matrix in the MRIO table. In some MRIO, like Eora,[1] industries in certain countries have more details and are disaggregated into sub-sectors. From a first glance, disaggregation of the satellite account according to the **T** matrix seems an easy task to tackle. However, databases usually have lots of challenges. One of these challenges, for example, is that satellite data have different classifications than the input-output table's classifications. For instance, suppose you want to calculate a footprint of a country and the input-output table of that country has 17 classifications (for instance, International Standard Industrial Classification of All Economic Activities ISIC, Rev.3). Assume the available raw data for the satellite account has only three sectors (Agriculture, Manufacturing and Services). To overcome this problem, you build what is called a concordance matrix that has 0 and 1 values. The value 1 is assigned where a sector in the raw data corresponds to those in the MRIO classification, and 0 where it does not (Fig. 2.2).

One of the well-known uses of the satellite accounts and especially those dealing with environmental indicators is to measure a footprint of a country. The *footprint* is the sum of, for instance, the emissions that are associated with products consumed within a country plus those embodied within the imported goods and services from the rest of the world, subtracted from the emissions associated with the exports of that country. In recent years, this footprint technique has been developed to be used for carbon (Hertwich and Peters 2009), material (Wiedmann et al. 2013), net primary production (Haberl et al. 2007), and others. However, the third pillar of sustainability (social) seems neglected. In this regard, here I have presented a novel approach to measuring the impact of international trade on social indicators within countries by calculating the footprints of nations.

2.3 Extended to Include Social Indicators

To establish a healthy society or a corporation, the three vehicles of sustainability (environmental, social and economic) need to be moved in parallel. While the social dimension has been neglected in the past, an effort by academia and researchers in

[1]See www.worldmrio.com.

international organizations to investigate the social aspect is now underway. However, thus far few attempts have been added to the literature. These include, for example; employment and wages (Alsamawi et al. 2014), inequality (see Chap. 9), occupational health and safety (Simas et al. 2014; Alsamawi et al. 2016), and child labour (Gomez-Paredes et al. 2016). In each of these social cases and others (e.g. environmental and economic indicators), the method used to measure the footprints of nations follows the same process. In this work, I will illustrate the footprints of employment, income, poverty and occupational health and safety of nations. As I mentioned before, a Multi-Regional Input-Output table will be coupled with a physical satellite account to calculate the footprints using Leontief's inverse technique. To make it explicit, suppose that the IO table has three sectors in a country and a satellite account **Q** holds the total amount of employment per each sector with an element Q_j (Table 2.1). In order to measure the amount of employment required for the production of one unit of total output, intensity coefficient matrix **q** is then calculated with elements q_j, where $q_j = Q_j/x_j$, Q_j hold a value of the employment satellite account into the production of sector j, and x_j is the total output of sector j.

The direct requirement matrix **A** of Table 2.1 can be expressed as

$$\mathbf{A} = (a_{ij}) = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = \begin{pmatrix} T_{11}/x_1 & T_{12}/x_2 & T_{13}/x_3 \\ T_{21}/x_1 & T_{22}/x_2 & T_{23}/x_3 \\ T_{31}/x_1 & T_{32}/x_2 & T_{33}/x_3 \end{pmatrix} \tag{2.1}$$

The gross output of sector i in Table 2.1 can be written as follow:

$$x_i = \sum_{j=1}^{3} T_{ij} + y_i \quad \text{from Eq. 2.1} \quad T_{ij} = a_{ij}x_j \tag{2.2}$$

Table 2.1 Input-output framework coupled with an employment satellite account

		Intermediate demand			Final demand	
		Agriculture	Manufacturing	Services	Gross national expenditure	Exports
Intermediate inputs	Agriculture	T Intermediate matrix			***y*** Final demand	
	Manufacturing					
	Services					
Value added	Gross domestic products	***v*** Value added to production				
	Imports					
Satellite account	Employment (FTE)	Agriculture	Manufacturing	Services		

then

$x_i = \sum_{j=1}^{3} a_{ij}x_j + y_i$ if we require to consider the entire economy, each parameter can be expressed as:

$$\boldsymbol{y} = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix}; \quad \mathbf{X} = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix};$$

Using Eqs. 2.1 and 2.2 and the fundamentals of matrix multiplication, we can find that the matrix **T** is equal to

$$\mathbf{T} = (\mathrm{T}_{ij}) = (a_{ij}x_j) = \begin{pmatrix} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix};$$

Thus,

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix}$$ and also can be written as

$$\mathbf{X} = \mathbf{AX} + \boldsymbol{y} \text{ and } \boldsymbol{y} = \mathbf{X} - \mathbf{AX} \Rightarrow \boldsymbol{y} = \mathbf{IX} - \mathbf{AX} \Rightarrow \boldsymbol{y} = (\mathbf{I} - \mathbf{A})\mathbf{X} \tag{2.3}$$

Multiplying both sides of Eq. 2.3[2] by(**I** − **A**) then

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\boldsymbol{y} \tag{2.4}$$

While **A** has the direct requirement of the production, the factor $(\mathbf{I}{-}\mathbf{A})^{-11}$, or what is well-known the Leontief inverse **L** $[\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-11}]$, has the direct and indirect links between sectors. Thus, the total output **X** in Eq. 2.4 can be represent as

$$\mathbf{X} = \mathbf{L}\boldsymbol{y} \tag{2.5}$$

By multiplying both sides of Eq. 2.5 by q, then $\mathbf{qX} = \mathbf{qL}\boldsymbol{y}$. Setting $m = \mathrm{qL}$, where m is a multiplier that show the amount of employment that is required directly (within a country) and indirectly (throughout a long supply chain) to satisfy the consumption of a population.

[2]**I** is an identity matrix. In matrix algebra, it has no effect on the equation and hence it has the same power as multiplying by one in an ordinary algebra.

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