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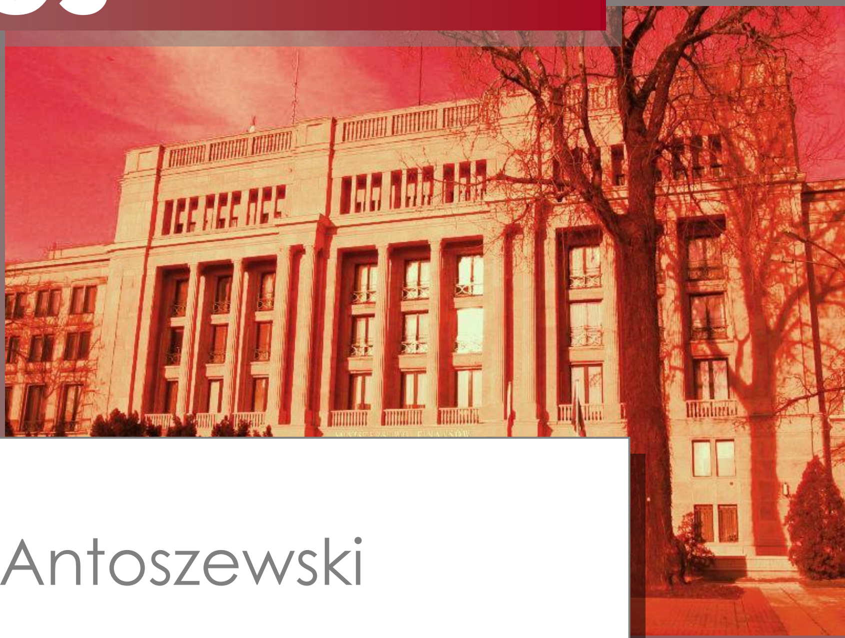

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Panel estimation of sectoral substitution elasticities for CES production functions

MINISTRY OF FINANCE
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Abstract

This paper provides a broad range of estimates of substitution elasticities for sectoral nested CES production functions, using panel data techniques, with the World Input-Output Database (WIOD) as the main data source. Although the related empirical literature has been growing over the recent years, there is still no single study focused on a large-scale estimation of various sectoral elasticities with a use of a common database and methodology. This paper constitutes an attempt to fill this gap. The obtained estimates may be subsequently used by Computable General Equilibrium (CGE) modellers in their applied research. A significant heterogeneity in estimated elasticity values is observed between various industries/products, as well as between various nests of the production function. This constitutes a strong argument against the arbitrary use of Leontief and/or Cobb-Douglas specifications in CGE models. It also turns out that, in most cases, obtained long-run elasticities are higher than in the short run. In addition, the analytical specification of estimated equation and time series properties of panel data (stationarity and cointegration) play a crucial role in determining the "correct" type of dynamic model (autoregressive distributed lag model, error correction model or model for differenced series) for a particular sector-nest combination and, in turn, in determining the preferred values of elasticity estimates.

Keywords: substitution elasticity, CES production function, panel data analysis

JEL classification: C23, C55, D57, Q43

The views expressed in this paper are solely those of the author and do not necessarily reflect those of the Ministry of Finance.

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1. Introduction

A common argument, which is often raised against the reliability of macroeconomic and sectoral analyses based on Computable General Equilibrium (CGE) models, originates from the fact their results are to a large extent determined by the assumed values of exogenous ("free") parameters that cannot be calibrated based on the data from National Accounts[1] – see Baccianti (2013), Broadstock et al. (2007), Fragiadakis et al. (2012), Koesler and Schymura (2012), Okagawa and Ban (2008), van der Werf (2008). The above mentioned set of "free" parameters includes mainly elasticities of substitution in production functions.

Németh et al. (2011) argued that the elasticities of substitution play such an important role in explaining CGE-based results since they determine the degree to which economic agents respond to price changes. They also distinguished two ways to obtain substitution elasticities for CGE models. The first one is statistical/econometric analysis, while the second one – implementation of externally estimated values from literature studies.

The problem is, however, that despite this meaningful role of elasticities, the empirical literature with estimates of required elasticities is still quite modest (Okagawa and Ban, 2008, Turner et al., 2012, van der Werf, 2008). As a result, CGE analysts often take advantage of elasticity values from unrelated sources and/or obtained from different conceptual frameworks. Zachłod-Jelec and Boratyński (2016) underlined the fact that the available empirical evidence is not only scarce, but also even ambiguous. They also argued that it is not an easy task to find appropriate estimates, tailored to a given CGE model, taking into account its specific sectoral and regional disaggregation, nesting structure or assumed interactions between economic agents.

Therefore, such an approach of employing (potentially) inconsistent elasticity estimates may be a reason for criticism regarding the use of CGE models (Koesler and Schymura, 2012, Németh et al. 2011). Kemfert (1998) explained those arbitrarily chosen elasticity values as "guestimations" that often replace econometric "estimations" in CGE-based analyses. Dawkins et al. (2001) even described such a behaviour of modellers as an "idiot's law of elasticities" (i.e. frequent use of unitary elasticities, equivalent to Cobb-Douglas function) and defined those arbitrarily chosen values as "coffee table elasticities". According to Turner et al. (2012), it is important to identify key parameters which may play the most crucial role in determining the results of CGE analyses. These parameters should be given a priority in estimation exercise, provided that appropriate data is available.

Against this backdrop, the main goal of this paper is a comprehensive, wide-range estimation of various types of substitution elasticities for CES functions, using a common database and common methodology. These estimates may be subsequently used by CGE modellers in their research work. Although the empirical literature related to elasticity estimation has been growing over the recent years, there is still no single study focused on a large-scale estimation of various sectoral elasticities with a use of a common database and methodology. Hence, this study constitutes an attempt to fill this identified gap.

This paper is divided into seven sections. The introduction in section 1 is followed by a description of the main characteristics of a (nested) CES production function and its role in empirical research in

[1] These sources are usually limited to Input-Output (I-O) data or Supply and Use Tables (SUT).

section 2. Section 3 provides a review of literature with similar conceptuality to this study. Section 4 describes data sources and necessary modifications made in order to prepare the final database. Sections 5 and 6 explain, respectively, econometric methodology applied and estimation results. Section 7 concludes.

2. (Nested) CES production function and elasticity of substitution

The most popular type of production function used in the empirical research (including the use of CGE models) is the Constant Elasticity of Substitution (CES) function, which originates from the seminal work of Arrow et al. (1961). In its most general from, CES function takes the following form:

$$Y_{i,t} = A_i \cdot \left[\alpha_i K_{i,t}^{\rho_i} + (1-\alpha_i) L_{i,t}^{\rho_i}\right]^{1/\rho_i}$$

where $Y_{i,t}$ stands for output (value added), while $K_{i,t}$ and $L_{i,t}$ – for factor inputs (capital and labour respectively). A_i is a parameter of technology (total factor productivity, TFP), α_i – capital income share, $(1-\alpha_i)$ – labour income share, while ρ_i is a determinant of substitution elasticity (σ_i). The elasticity of substitution is defined as $\sigma_i = \frac{1}{1-\rho_i}$. Subscripts i and t denote sectoral (industrial) and time dimensions respectively.[2]

In particular, CES function is a general form of Cobb-Douglas and Leontief production functions. The former is defined as: $Y_{i,t} = A_i K_{i,t}^{\alpha_i} L_{i,t}^{1-\alpha_i}$, while the latter as: $Y_{i,t} = A_i \cdot min\{\alpha_i K_{i,t}, (1-\alpha_i) L_{i,t}\}$. The same parameter definitions as previously hold.

It follows that $0 \neq \rho_i < 1$, which implies that $\sigma_i > 0$. Hence, these constraints imply the non-negativity of substitution elasticity. With $\rho_i \approx 0$, the elasticity of substitution approaches unity $(\sigma_i \approx 1)$ and CES function reduces to Cobb-Douglas form. With $\rho_i \to \infty$, the elasticity of substitution approaches zero $(\sigma_i \approx 0)$ and CES function reduces to Leontief form. Tipper (2012) provides an in-depth explanation of CES production function theory.

The underlying economic theory distinguishes between many definitions of a substitution elasticity. Marginal rate of technical substitution (MRTS), Hicks/Direct Elasticity of Substitution (HES), Cross Price Elasticity (CPE), Allen-Uzawa Elasticity of Substitution (AES) and Morishima Elasticity of Substitution (MES) are the most prominent measures of elasticity (Broadstock et al., 2007). Broadstock et al. (2007) also argued that an appropriate measure of substitution elasticity, consistent with CES functions applied in most of the CGE models, is the Hicksian elasticity of substitution – HES[3] (Hicks, 1932), defined as[4]:

$$\sigma_i = \frac{\partial\left(\frac{K_{i,t}}{L_{i,t}}\right) / \left(\frac{K_{i,t}}{L_{i,t}}\right)}{\partial\left(\frac{w_{i,t}}{r_{i,t}}\right) / \left(\frac{w_{i,t}}{r_{i,t}}\right)}.$$

[2] It is apparent that not all the parameters are not assigned a time subscript t. This results from the fact that they are either calibrated to the base-year data (distribution/share and technology parameters) or set exogenously (substitution elasticity), and assumed to be constant over time.
[3] Zachłod-Jelec and Boratyński (2016) underlined that empirical studies apply several definitions of substitution elasticities, but only a few of them use the HES measure, consistent with CES functions applied in CGE models.
[4] See Broadstock et al. (2007), as well as Tipper (2012) for more details.

Under this definition, the substitution elasticity measures the percentage change in factor input proportions (in this case: capital-labour ratio) relative to the percentage change in factor price proportions (in this case: wage to capital rental ratio) – keeping output level fixed.[5] Therefore, this elasticity may be interpreted either as the ease of compensating a decrease in one input with an increase in another one (keeping output constant) or as the ease of changing input composition in response to changes in their relative prices. HES has been originally tailored to production functions with two inputs only. However, this measure may be generalised to production functions with multiple inputs, called Direct Elasticity of Substitution (Chambers, 1988). Hence, the common name "Hicks/Direct Elasticity of Substitution" holds.

While the distribution parameter α_i is typically assigned a sector-specific value (i.e. calibrated), using the information from Input-Output or Supply and Use Tables, the value of parameter σ_i under the CES framework needs to be assigned exogenously, i.e. from outside the database that a given CGE model is based on. Calibration of the elasticity coefficient ρ_i (and hence parameter σ_i) allows for a subsequent calibration of the technology parameter:

$$A_i = \frac{Y_{i,t}}{\left[\alpha_i K_{i,t}^{\rho_i} + (1-\alpha_i) L_{i,t}^{\rho_i}\right]^{1/\rho_i}}.$$

However, such a simplified framework significantly restricts the underlying production structure as it assumes equal substitution elasticity between all inputs (Koesler and Schymura, 2012, Henningsen and Henningsen, 2011). To address this issue, Sato (1967) introduced a two-level, "nested" CES function, in which all or some of the inputs at the "upper" level of production process may be represented by another CES function of further sub-inputs at the "lower" level. It is quite easy to illustrate the idea of a two-level, nested CES function with a simple example. Suppose that at the top nest, the output $(Y_{i,t})$ is a CES function of value added $(VA_{i,t})$ and intermediate inputs $(II_{i,t})$:

$$Y_{i,t} = A_{i,1} \cdot \left[\alpha_{1,i} \cdot VA_{i,t}^{\rho_{1,i}} + (1-\alpha_{1,i}) \cdot II_{i,t}^{\rho_{1,i}}\right]^{1/\rho_{1,i}}.$$

At the lower nest, the value added is itself represented by a CES function of capital $(K_{i,t})$ and labour $(L_{i,t})$ – similarly to the previous example:

$$VA_{i,t} = A_{2,i} \cdot \left[\alpha_{2,i} \cdot K_{i,t}^{\rho_{2,i}} + (1-\alpha_{2,i}) \cdot L_{i,t}^{\rho_{2,i}}\right]^{1/\rho_{2,i}}.$$

The elasticities of substitution at the upper (top) and lower nest are given by $\sigma_{1,i} = \frac{1}{1-\rho_{1,i}}$ and $\sigma_{2,i} = \frac{1}{1-\rho_{2,i}}$ respectively. Distribution parameters $\alpha_{i,1}$ and $(1-\alpha_{i,1})$ stand for the shares of value added and intermediate inputs in gross output respectively. Distribution parameters $\alpha_{i,2}$ and $(1-\alpha_{i,2})$ are defined as the shares of capital and labour income in value added respectively. Technology parameters $A_{i,1}$ and $A_{i,2}$ measure total factor productivity (TFP) in the production process of gross output and value added respectively.

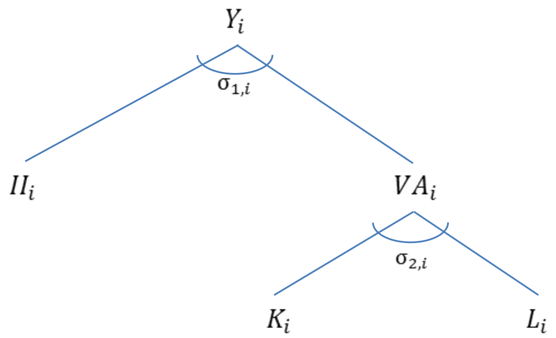
[5] In fact, HES is a symmetric measure, hence an inversion of ratios of input quantities and prices does not change its value.

These two separate production functions may be analytically combined into a nested CES function:

$$Y_{i,t} = A_{1,t} \cdot \left\{ \alpha_{1,t} \cdot \left[A_{2,t} \cdot \left(\alpha_{2,t} \cdot K_{i,t}^{\rho_2} + (1 - \alpha_{2,t}) \cdot L_{i,t}^{\rho_2} \right)^{1/\rho_{2,t}} \right]^{\rho_{1,t}} + (1 - \alpha_{1,t}) \cdot II_{i,t}^{\rho_{1,t}} \right\}^{1/\rho_{1,t}}.$$

Figure 1 provides a graphical representation of such a two-level, nested CES production function.

Figure 1. Two-level, nested CES production structure

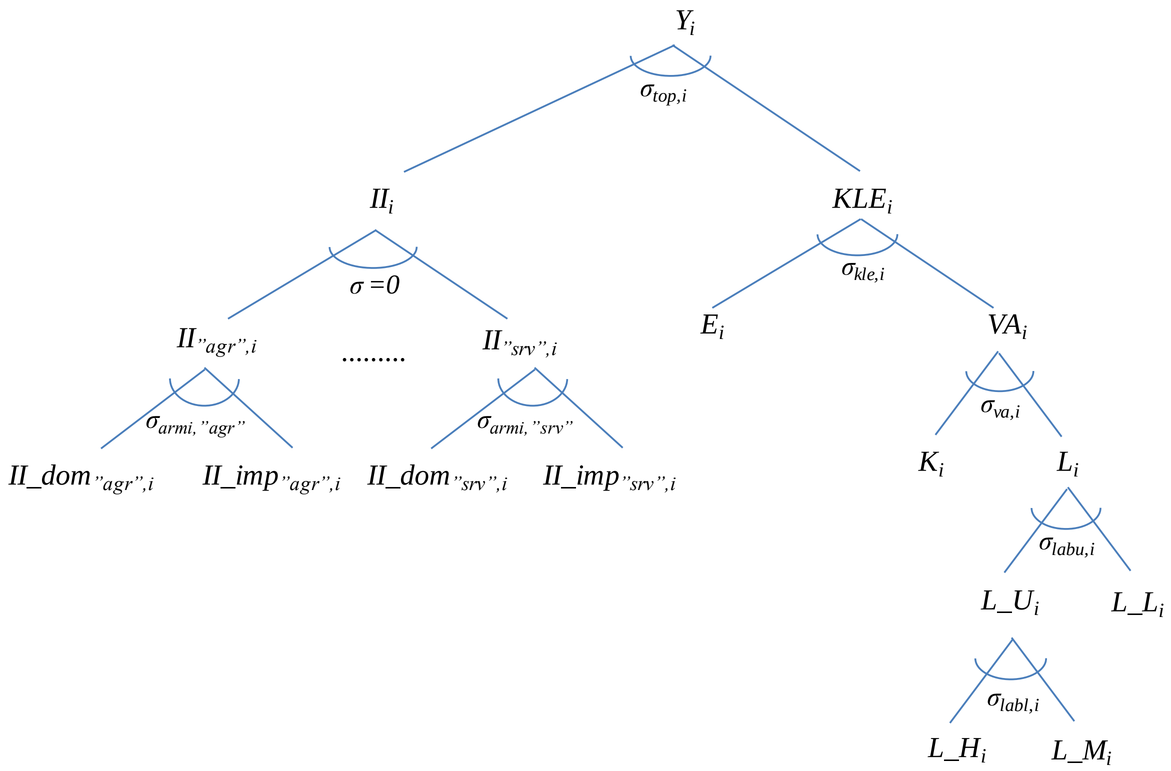


Source: Own elaboration

Obviously, the concept of a two-level CES may be easily extended to more complicated nesting structures, both in terms of number of nests and the correspondence between them. Figure 2 provides a graphical representation of a nesting structure used in the estimation procedure for the purpose of this paper. At the top level, output consists of (non-energy) intermediate inputs (II) and capital-labour-energy (KLE) composite. Intermediate inputs in a given industry (II) constitute a Leontief combination of all intermediate product composites (II_Arm). These are Armington (1969) composites that combine domestic (II_dom) and imported (II_imp) bundles for each of the products used by a given industry. KLE composite is made up of value added (VA) and energy bundle. Value added is a product of capital (K) and labour (L), the latter consisting of upper-skilled (L_U) and low-skilled (L_L) labour inputs. At the bottom nest, upper-skilled labour constitutes a product of high- (L_H) and medium-skilled (L_M) labour. In particular, each nest (except for the Armington nest) is characterised by its own, sector-, or industry-specific elasticity value (hence the presence of subscript i). Elasticities within the Armington nest are product-, or good-specific (hence the presence of subscript g) and industry-uniform.[6]

[6] Such an approach stems from the fact that Armington (1969) actually introduced his concept as products' (goods') differentiation by the source of origin.

Figure 2. Multi-level, nested CES production structure used in the estimation procedure



Source: Own elaboration

3. Literature review

As previously mentioned, the empirical evidence on estimates of substitution elasticities is still quite modest. In addition, different papers are focused on different definitions of elasticities, functional forms, databases used (with different regional and sectoral coverage and different time slice), and use different econometric techniques (Zachłod-Jelec and Boratyński, 2016). Some of the reported estimation outcomes even seem to be contradictive. Within this context, this chapter describes the main findings from relatively new econometric literature based on panel data analysis of various production function nests under the CES framework.

Baccianti (2013) estimated substitution elasticities between capital, labour and energy within one-nest CES function with factor-augmenting technological change. Besides, three alternative nesting structures – (KL)E, (KE)L and (LE)K were assessed.[7] The panel estimation with fixed effects was based on a dataset covering 27 countries and 33 industries within the time span 1995-2008, which combined information from World Input-Output Database Socio-Economic Accounts (WIOD SEA) and IEA/OECD Energy Prices and Taxes. In order to improve the identification of estimated parameters, the production function was subject to normalisation procedure. The author concluded that most of the estimated elasticity values were located below unity (i.e. there are rather low substitutions possibilities), which implies an increase in cost share of the input getting relatively more expensive. The only exception is the substitutability between capital and labour within the value added nest

[7] (KL)E structure implies that capital and labour are aggregated into a capital-labour composite at the lower nest, which is subsequently combined with energy at the upper nest. The analogical interpretation holds for all the remaining structures.

under the (KL)E structure, for which the Cobb-Douglas specification of unitary elasticity is justified. The same findings hold at the whole economy's level, after aggregation over the activity sectors.

Fragiadakis et al. (2012) estimated substitution elasticities between capital and labour in a CES framework with total factor productivity growth, using pooled data techniques. They also took advantage of the WIOD SEA database for the period 1995-2009, aggregated into six economic sectors. Besides, three pooled datasets for three groups of regions were constructed. The authors concluded that – in most cases – the values of short-run elasticities were lower than one (i.e. Cobb-Douglas specification) and sometimes even close to zero (i.e. Leontief specification), while long-run elasticities are located above unity.

Koesler and Schymura (2012) estimated three-level nested CES functions, of a (KL)E-M form[8], either with the Hicks neutral technological change (i.e. TFP) or without any technical progress, using non-linear econometric techniques for pooled data. Estimation was based on WIOD Socio-Economic Accounts and WIOD Energy Use datasets. These formed a balanced panel of 40 regions in 1995-2006 period for each of 35 sectors. The authors argued that the common practice of using Cobb-Douglas or Leontief production functions in applied CGE analyses must be rejected in most of the cases, given the complexity and heterogeneity of obtained estimates across sectors.

Németh at al. (2011) provided estimates of Armington elasticities for two-level nested CES – with domestic-imported goods choice at the upper nest and with intra-import choice between various countries of origin at the lower nest. This was aimed at reflecting Armington (1969) assumption. The econometric estimation was based on panel data techniques (with fixed and random effects at the upper and lower nest respectively). Data sources included Eurostat's COMEXT and National Accounts databases over the period 1995-2005. The authors drew a conclusion that relative demand changes in reaction to relative price changes were less sensitive between domestic and imported bundles (upper nest) than within the intra-import basket (lower nest), with higher elasticity values obtained in the latter case. Moreover, short-term elasticities tended to be lower than long-term ones in most cases.

Okagawa and Ban (2008) estimated substitution elasticities for two types of three-level, nested CES functions, namely for (KE-L)(MS) and (KL-E)(MS) structures[9] – with the main focus on substitution possibilities between capital, labour an energy. All the calculations were based on KLEMS database, from which the panel dataset for each of 19 industries, covering 14 OECD countries in the time range 1995-2004, was derived. They found higher elasticity values at the top nests (combining KLE composite and intermediates), as compared with the lower nests (combining capital-energy and their composite with labour, as well as combining capital-labour and their composite with energy). The authors could not reject the null hypothesis of zero substitution (i.e. of Leontief specification) between capital and energy for most of the sectors. With respect to elasticities between capital-energy composite and labour, as well as between capital-labour composite and energy, they could not reject the null hypothesis of unitary substitution (i.e. of Cobb-Douglas form) in almost all of the sectors.

[8] "M" stands for materials, i.e. non-energy intermediate inputs.
[9] „MS" stands for „materials + services", i.e. intermediate inputs under the convention applied in this paper.

Saito (2004) estimated Armington elasticities of substitution between domestic and imported bundles of commodity aggregates (*intergroup elasticities* – estimated from multilateral data), as well as between import baskets from various countries of origin (*intragroup elasticities* – estimated from bilateral data), using panel data techniques with fixed effects. Her dataset included information from International Sectoral Data Base and International Trade by Commodities Statistics, covering 14 regions in the period 1970-90. In addition, OECD Input-Output Database was also used for auxiliary calculations. Actually, *intergroup elasticities* were treated as country-specific (estimation based on each country's time series), while *intragroup elasticities* – as country-uniform (based on panel data of all 14 countries). The author concluded that *intergroup elasticities* (estimated from multilateral data) were higher than *intragroup elasticities* (obtained from bilateral trade data) in the intermediate input sectors, but equal or lower in the final consumptions sectors.

Van der Werf (2008) concentrated on empirical verification (with the use of pooled data techniques) of three important elements of each CGE model, i.e. of production (nesting) structure, substitution possibilities and technological change, His database was constructed on the basis of IEA Energy Balances and OECD International Sectoral Database, creating a panel for of 12 countries, 7 industries and with the time span 1978-1996. The author provided an empirical evidence of all possible nesting structures for capital-energy-labour (KEL) composite under the CES framework. He concluded that the (KL)E nesting structure (where capital and labour are combined first into value added component and then put together with energy) fitted the historical data best, with country- and sector-specific elasticity values significantly lower than unity (statistical rejection of Cobb-Douglas function). In addition, the null hypothesis of total factor (i.e. Hicks-neutral) productivity growth should be rejected in favour of factor-augmenting (i.e. input-specific) technical change.

4. Data sources

The undertaken econometric analysis has been based on panel data techniques. By combining cross section and time series variability, panel estimation allows for a better distinction between input substitution and technological change than time series analysis (Baccianti, 2013). In addition, Németh et al. (2011) suggested that the use of panel data enables to account for individual heterogeneity between cross-sections and to control for therefore biased results, as well as helps in overcoming multicollinearity problems that occur in time series analysis.

Since the undertaken approach to substitution elasticity estimation requires both price and quantity data for various macroeconomic categories, the following data sources have been extensively used to produce a final database:

- *WIOD Socio-Economic Accounts (WIOD SEA)*;
- *WIOD Energy Use (WIOD EU)*;
- *WIOD World Input-Output Tables (WIOT);*
- *WIOD National Input-Output Tables (NIOT);*
- *OECD Energy Prices and Taxes*.

The first four of them are parts of the World Input-Output Database (Timmer et al., 2015) – a consistent dataset with comprehensive sectoral coverage (Koesler and Schymura (2012). According to the official webpage[10], *The World Input-Output Database (WIOD) provides time-series of world*

[10] http://www.wiod.org

input-output tables for forty countries worldwide and a model for the rest-of-the-world, covering the period from 1995 to 2011. These tables have been constructed in a clear conceptual framework on the basis of officially published input-output tables in conjunction with national accounts and international trade statistics. In addition, the WIOD provides data on labour and capital inputs and pollution indicators at the industry level that can be used in conjunction enlarging the scope of possible applications.

There are several papers that take advantage of WIOD SEA as a main data source, including Baccianti (2013), Fragiadakis et al. (2012), Koesler and Schymura (2012). In particular, the last two of them exploit WIOD Energy Use database as well. The examples of other panel data sources employed in the literature include Eurostat's National Accounts and COMEXT (Németh et al., 2011), EU KLEMS (Okagawa, Ban, 2008), IEA Energy Balances and OECD International Sectoral Database (Saito, 2004, van der Werf, 2008), as well as OECD International Trade by Commodities Statistics and OECD Input-Output Database (Saito, 2004).

Table 1 contains the set of variables in WIOD SEA database (17 out of 25 available items) that have been used in order to construct the final database.

Table 1. WIOD SEA variables used in the process of database preparation

VARIABLE	DESCRIPTION
GO	Gross output by industry at current basic prices (in millions of national currency)
II	Intermediate inputs at current purchasers' prices (in millions of national currency)
VA	Gross value added at current basic prices (in millions of national currency)
LAB	Labour compensation (in millions of national currency)
CAP	Capital compensation (in millions of national currency)
GFCF	Nominal gross fixed capital formation (in millions of national currency)
H_EMP	Total hours worked by persons engaged (millions)
GO_P	Price levels of gross output, 1995=100
II_P	Price levels of intermediate inputs, 1995=100
VA_P	Price levels of gross value added, 1995=100
K_GFCF	Real fixed capital stock, 1995 prices
LABHS	High-skilled labour compensation (share in total labour compensation)
LABMS	Medium-skilled labour compensation (share in total labour compensation)
LABLS	Low-skilled labour compensation (share in total labour compensation)
H_HS	Hours worked by high-skilled persons engaged (share in total hours)
H_MS	Hours worked by medium-skilled persons engaged (share in total hours)
H_LS	Hours worked by low-skilled persons engaged (share in total hours)

Source: Timmer et al. (2015)

In order to construct the final database, the categories described above have had to be put under transformation – this idea has been partially derived from Fragiadakis et al. (2012). Table 2 provides details of this procedure. Notably, the subscripts *r*, *i* and *t* stand for regional (country), sectoral and time dimensions respectively.

Table 2. Variables created for estimation purposes

Code	Definition	Formula
LABH	Labour compensation (millions of national currency), high-skilled persons	$LABH_{r,i,t} = LABHS^*_{r,i,t} \cdot LAB^*_{r,i,t}$
LABM	Labour compensation (millions of national currency), medium-skilled persons	$LABM_{r,i,t} = LABMS^*_{r,i,t} \cdot LAB^*_{r,i,t}$
LABL	Labour compensation (millions of national currency), low-skilled persons	$LABL_{r,i,t} = LABLS^*_{r,i,t} \cdot LAB^*_{r,i,t}$
LABU	Labour compensation (millions of national currency), upper-skilled persons	$LABU_{r,i,t} = LABH_{r,i,t} + LABM_{r,i,t}$
H_H	Total hours worked by high-skilled persons (millions)	$H\_H_{r,i,t} = H\_HS^*_{r,i,t} \cdot H\_EMP^*_{r,i,t}$
H_M	Total hours worked by medium-skilled persons (millions)	$H\_M_{r,i,t} = H\_MS^*_{r,i,t} \cdot H\_EMP^*_{r,i,t}$
H_L	Total hours worked by low-skilled persons (millions)	$H\_L_{r,i,t} = H\_LS^*_{r,i,t} \cdot H\_EMP^*_{r,i,t}$
H_U	Total hours worked by upper-skilled persons (millions)	$H\_U_{r,i,t} = H\_H_{r,i,t} + H\_M_{r,i,t}$
PG	Price level of gross output (1995=100)	$PG_{r,i,t} = GO\_P^*_{r,i,t}$
PI	Price level of intermediate inputs (1995=100)	$PI_{r,i,t} = II\_P^*_{r,i,t}$
PV	Price level of gross value added (1995=100)	$PV_{r,i,t} = VA\_P^*_{r,i,t}$
PL	Price level of labour (1995=100)	$PL_{r,i,t} = \frac{LAB^*_{r,i,t}/H\_EMP^*_{r,i,t}}{LAB^*_{r,i,"1995"}/H\_EMP^*_{r,i,"1995"}} \cdot 100$
PLU	Price level of upper-skilled labour (1995=100)	$PLU_{r,i,t} = \frac{LABU_{r,i,t}/H\_U_{r,i,t}}{LABU_{r,i,"1995"}/H\_U_{r,i,"1995"}} \cdot 100$
PLL	Price level of low-skilled labour (1995=100)	$PLL_{r,i,t} = \frac{LABL_{r,i,t}/H\_L_{r,i,t}}{LABL_{r,i,"1995"}/H\_L_{r,i,"1995"}} \cdot 100$
PK	Price level of capital (1995=100)	$PK_{r,i,t} = \frac{CAP^*_{r,i,t}/K\_GFCF^*_{r,i,t}}{CAP^*_{r,i,"1995"}/K\_GFCF^*_{r,i,"1995"}} \cdot 100$
QG	Gross output volume at 1995 prices (millions of national currency)	$QG_{r,i,t} = \frac{GO^*_{r,i,t}}{PG_{r,i,t}} \cdot 100$
QI	Intermediate inputs volume at 1995 prices (millions of national currency)	$QI_{r,i,t} = \frac{II^*_{r,i,t}}{PI_{r,i,t}} \cdot 100$
QV	Gross value added volume at 1995 prices (millions of national currency)	$QV_{r,i,t} = \frac{VA^*_{r,i,t}}{PV_{r,i,t}} \cdot 100$
QL	Labour input volume at 1995 prices (millions of national currency)	$QL_{r,i,t} = \frac{LAB^*_{r,i,t}}{PL_{r,i,t}} \cdot 100$
QLU	Upper-skilled labour input volume at 1995 prices (millions of national currency)	$QLU_{r,i,t} = \frac{LABU_{r,i,t}}{PLU_{r,i,t}} \cdot 100$
QLL	Low-skilled labour input volume at 1995 prices (millions of national currency)	$QLL_{r,i,t} = \frac{LABL_{r,i,t}}{PLL_{r,i,t}} \cdot 100$
QK	Capital input volume at 1995 prices (millions of national currency)	$QK_{r,i,t} = \frac{CAP^*_{r,i,t}}{PK_{r,i,t}} \cdot 100$

Source: Own elaboration based on Fragiadakis et al. (2012) and Timmer et al. (2015)

Note: asterisks (*) indicate original WIOD items, while grey font – auxiliary variables that do not directly take part in the estimation process.

A certain limitation of WIOD SEA database is related to the fact that the industry-specific variables associated with Intermediate inputs value (II), as well as their prices (II_P) and quantities (II_QI) have not been split into particular products, as well as into domestic and imported flows. This in turn prevents direct estimation of (product-, not industry-specific) Armington elasticities, using this database as the only data source. In addition, intermediate input variables contain also the use of energy products within each industry, which should be excluded for the sake of proper estimation of substation elasticities between intermediate inputs and energy at the top nest of production function. The essential disaggregation of intermediate input flows, as well as the subtraction of energy products, is however possible with the use of National Input-Output Tables and World Input-Output Tables. A similar procedure (but based on different data sources) has been previously used by Saito (2004). Based on economic flows observed in NIOT and WIOT, it was possible to track source (domestic/imported), country of origin and product mix used by a given industry in a given country. This information, combined with using gross output prices (GO_P) as a proxy of unit cost of purchase of a given intermediate input (product) from domestic source or as an import from a given country, enabled to subtract the use of energy products from intermediate input values (II) and price indices (II_P) for a given industry, as well as to subsequently divide intermediate inputs (II) into domestic (II_dom) and imported (II_imp, an aggregate over all regions) flows, and into particular products, thus including source of origin and product dimensions to these variables. Subsequently, this data has been aggregated over industries, leaving product, source of origin and time dimensions. The data from NIOT and WIOT has also enabled to construct domestic and imported intermediate input price indices for each product in each country. Finally, the availability of domestic and imported input values and prices enabled to construct domestic and imported input quantity variables. As a result, the following variables (product- and country-specific) have been created:

- $PD_{r,g,t}$ – price level of domestic intermediate inputs (1995=100);
- $PM_{r,g,t}$ – price level of imported intermediate inputs (1995=100);
- $QD_{r,g,t}$ – domestic intermediate inputs volume at 1995 prices (millions of national currency);
- $QM_{r,g,t}$ – imported intermediate inputs volume at 1995 prices (millions of national currency).

The last of the above mentioned databases – *OECD Energy Prices and Taxes* – has also had to be used due to the fact that *WIOD Socio-Economic Accounts* do not separate energy from intermediate use as an individual product, while WIOD Energy Use provides only data on used energy quantities, without any information on energy prices. Therefore, following Baccianti (2013), industry- and country-specific time series of energy prices have been constructed based on OECD data:

- $PE_{r,i,t}$ – aggregate price level of energy (1995=100);
- $QE_{r,i,t}$ – gross energy use in TJ.

In addition, WIOD does not provide ready-to-use data for capital-labour-energy (KLE) aggregate, i.e. the product of the nest with elasticity $\sigma_{kle,i}$. This quantity and price (unit cost) data for KLE composite is actually essential for estimation of substitution elasticity between KLE bundle and intermediate input composite (within the nest with elasticity $\sigma_{top,i}$). Therefore, industry- and country-specific time series for capital-labour-energy composite (KLE) have also been constructed:

- $PKLE_{r,i,t}$ – aggregate price level of capital-labour-energy composite (1995=100);
- $QKLE_{r,i,t}$ – capital-labour-energy composite volume at 1995 prices (millions of national currency).

In the process of merging information from various databases, yet another issue has had to be addressed. WIOD Input-Output Tables and WIOD Socio-Economic Accounts provide data for 35 activity sectors and 40 countries/regions[11] of the world economy (see Tables 3-4) for the period 1995-2011, while WIOD Energy Use additionally offers information on energy consumption from 26 energy carriers (as a fourth dimension) over the period 1995-2009. However, this data needs to be combined with information from OECD Energy Prices and Taxes database (category "Energy prices in national currency per toe"[12]) that covers 34 countries and 14 fuels over the time span 1978-2016. A product of this mapping procedure is a final, partially unbalanced[13], database covering 34 sectors[14] and 26 countries (common for all data sources[15]) with a time span 1995-2009. In particular, while reconciling different energy carriers from WIOD and OECD databases, 15 out of 26 WIOD fuel have been used in a calculation of a common energy price index.[16]

Finally, all the quantity data has been transformed into level indices, with 1995 as a base year. However, this transformation has been performed only for the purpose of preliminary data analysis, which has been much easier for quantity indices than for quantity levels (with various units of measurement). Tipper (2012)[17] explained that the use of quantity Indices instead of levels does not impact elasticity estimates, since these are invariant to measurement units.[18]

[11] Plus Rest oi the World (ROW) region, which is however not present in WIOD Socio-Economic Accounts and is therefore excluded from further analysis.
[12] In order to address the issue of missing data, information from the category "Indices of energy prices by sector" was also used to some extent.
[13] There are some missing data items, especially for the variables associated with capital in 2008 and 2009. In addition, observations for single countries have also been discarded in few cases in order to get rid of data outliers. However, this operation has comprised only 14 out of all 204 sector-nest combinations.
[14] Excluding sector "Private Households with Employed Persons", for which the lack of data on capital compensation (CAP) and capital stock (K_GFCF) in WIOD SEA made the construction of capital input (QK) and capital price (PK) variables impossible.
[15] Although there are actually as much as 29 countries common for all data sources, Latvia, Luxembourg and Turkey were excluded from the sample due to the large number of missing data items.
[16] For more details of this concordance scheme, see Tables 19-20 in Annex.
[17] Actually, he referred to Coelli et al. (2005) as the source of this concept.
[18] In fact, a test estimation, undertaken based on the constructed database, has confirmed this finding.

Table 3. Sectoral disaggregation of World Input-Output Database (WIOD)

Industry	NACE 1.1	Code
Agriculture, hunting, forestry and fishing	AtB	agr
Mining and quarrying	C	min
Food, beverages and tobacco	15t16	foo
Textiles and textile products	17t18	tex
Leather, leather and footwear	19	lea
Wood and products of wood and cork	20	woo
Pulp, paper, printing and publishing	21t22	ppp
Coke, refined petroleum and nuclear fuel, industrial gas	23	pet
Chemicals and chemical products	24	chm
Rubber and plastics	25	rub
Other non-metallic mineral	26	nmm
Basic metals and fabricated metal	27t28	mtl
Machinery, nec	29	mch
Electrical and optical equipment	30t33	eeq
Transport equipment	34t35	teq
Manufacturing, nec; recycling	36t37	oth
Electricity, gas and water supply	E	ele
Construction	F	con
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50	mvh
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	whs
Retail trade, except of motor vehicles and motorcycles; repair of household goods	52	trd
Hotels and restaurants	H	htl
Inland transport	60	ltr
Water transport	61	wtr
Air transport	62	atr
Other supporting and auxiliary transport activities; activities of travel agencies	63	trv
Post and telecommunications	64	com
Financial intermediation	J	fin
Real estate activities	70	rea
Renting of m&eq and other business activities	71t74	ren
Public administration and defence; compulsory social security	L	pub
Education	M	edu
Health and social work	N	hea
Other community, social and personal services	O	srv
Private households with employed persons	P	

Source: Own elaboration based on Timmer et al. (2015)

Note: grey font indicates the sector excluded from further analysis due to missing data (see Footnote 13).

Table 4. Countries covered by the final database used in the estimation procedure

AUS	Australia	DEU	Germany	POL	Poland
AUT	Austria	GRC	Greece	PRT	Portugal
BEL	Belgium	HUN	Hungary	SVK	Slovak Republic
CAN	Canada	IRL	Ireland	SVN	Slovenia
CZE	Czech Republic	ITA	Italy	ESP	Spain
DNK	Denmark	JPN	Japan	SWE	Sweden
EST	Estonia	KOR	Korea, Republic of	GBR	United Kingdom
FIN	Finland	MEX	Mexico	USA	United States
FRA	France	NLD	Netherlands		

Source: Own elaboration based on Timmer et al. (2015)

5. Methodology and econometric techniques applied

CES function is non-linear in parameters, which implies that its parameters cannot be directly estimated with standard linear regression techniques, using Ordinary Least Squares (OLS). Henningsen and Henningsen (2011) argued that econometric estimation of substitution elasticities is not frequently undertaken due to this limitation. To address this issue, they developed R-package micEconCES, tailor-made for direct, non-linear estimation of substitution elasticities within (nested) CES functions, without a need to deliver price data as an estimation input.[19] However, this last aspect constitutes a disadvantage rather than an advantage of this package, since the use of price data is essential for an appropriate estimation of Hicks/Direct Elasticity of Substitution (HES) – see Broadstock et al. (2007). Another problem with non-linear estimation is the need to provide starting values of estimated parameters and to reach estimation convergence. In fact, Koesler and Schymura (2012) admitted that, in several cases, they had not managed to achieve an acceptable level of convergence in their own estimation. An alternative approach to non-linear estimation is Kmenta (1967) approximation, which may however yield potentially biased and inconsistent results (Thursby and Lovell, 1978). In addition, Maddala and Kadane (1967) pointed to the fact that Kmenta approximation does not always result in reliable estimates of substitution elasticities.

Against this backdrop, another method – OLS estimation of linearised equations – has been applied. The equations to be estimated may be derived from first order conditions either for profit maximisation or for cost minimisation problem. This stems from the fact that, under the price-taking assumption of firms' behaviour, profit maximisation problem is equivalent to cost minimisation problem (Mas-Colell et al., 1995). Both approaches enable to obtain the relations of conditional factor demands as a function of their price ratios. These relations may be subsequently log-transformed and become subject to econometric estimation. Among the reviewed studies, profit maximisation with respect to underling production function was applied by Baccianti (2003), Balistreri et al. (2003), Fragiadakis et al. (2012), as well as Németh et al. (2011). Cost minimisation with respect to the underlying production function was applied by Okagawa and Ban (2008), as well as van der Werf (2008).

Another aspect of crucial importance is the distinction between short-term and long-term elasticities. For CGE-based analyses, long-run elasticity values are much more appropriate (Balistreri et al., 2003). Thus, the dynamic properties of panel data – through the inclusion of time adjustments in estimation procedure – need to be taken into account. Consequently, it becomes extremely important to

[19] Among the reviewed articles, Koesler and Schymura (2012) took advantage of micEconCES package.

carefully test for stationarity and cointegration in order not to obtain spurious results (Fragiadakis et al., 2012, Balistreri et al., 2003). In this context, another drawback of micEconCES package is the disregard of panel data properties in time dimension (i.e. panel stationarity, cointegration, lagged adjustments) and therefore no distinction between short- and long-run elasticities. This distinction was made by Fragiadakis et al. (2012), Németh et al. (2011)[20], Tipper (2012), and – for US time series data – by Balistreri et al. (2003). Indeed, most of the reviewed studies did not account for this distinction, nor for stationarity and cointegration: Baccianti (2003), Claro (2003), Kemfert (1998), Koesler and Schymura (2012), Okagawa and Ban (2008), Saito (2004), Turner et al. (2012).[21]

The empirical verification of the nesting structure, described in section 2 and shown in Figure 2, has not been undertaken for several reasons. Most importantly, a production function with such a complicated nesting structure would be extremely difficult to estimate. In fact, the previous econometric estimations of CES function, conducted by Kemfert (1998) and van der Werf (2008), were merely focused on the various ways of nesting capital, labour and energy (KLE) inputs only. They both concluded that the KL(E) nesting (where capital and labour constitute a value added composite that is subsequently combined with energy) is mostly appropriate in terms of fitting the historical data.[22] This nesting scheme was also adopted by Koesler and Schymura (2012). Hence, it has also been applied within the nest with substitution elasticity $\sigma_{kle,i}$. In addition, WIOD Socio-Economic Accounts provide ready-to-use data for KL (i.e. value added) composite together with its price. The choice of another nesting would require a significant rearrangements in this database, which could in turn undermine its consistency and quality. Moreover, the authors who directly estimated production function nestings, did not account for stationarity and cointegration issues. Particular elasticities have also been estimated separately for each nest. Links between the nests are ensured by the use of a common database, analogically to Németh et al. (2011).

The econometric approach used in this paper combines the advantages of methodologies applied by Fragiadakis et al. (2012), as well as Okagawa and Ban (2008). At its roots, it is based on a standard profit maximisation problem. For illustrative purposes, the algebra outlined in this section describes the estimation procedure for value added bundle, consisting of labour and capital inputs (nest with elasticity $\sigma_{va,i}$). Analogous schemes hold for all other nests, as shown in Figure 2. Acronyms of variables and subscripts are also consistent with those presented in Table 2.

An economic agent in sector i maximises the profit from producing value added (capital-labour bundle) in period t subject to the underlying production function (country subscripts omitted here for simplicity):

$$\max_{QK_{i,t},QL_{i,t}} \{\Pi_i = PV_{i,t} \cdot QV_{i,t} - PK_{i,t} \cdot QK_{i,t} - PL_{i,t} \cdot QL_{i,t}\}$$

$$s.t.\ \ QV_{i,t} = A_i \cdot \left[\alpha_i \cdot QK_{i,t}^{\rho_i} + (1-\alpha_i) \cdot QL_{i,t}^{\rho_i}\right]^{1/\rho_i}.$$

[20] Actually, they included lags of dependent variables in their regressions, but without explicit testing for stationarity and cointegration.

[21] Baccianti (2003) advocated that the weak power of panel unit root tests under relatively small sample in time dimension justifies the *ad-hoc* use of variables in levels.

[22] However, Baccianti (2003) argues that such R^2-based assessments provided by Kemfert (1998) may be contested, because models with different dependent variables were actually compared. A similar critique might also be applied to van der Werf (2008).

First order conditions (FOCs) of the above optimisation problem yield:

$$\frac{QK_{i,t}}{QL_{i,t}} = \left(\frac{1-\alpha_i}{\alpha_i}\right)^{\frac{1}{\rho_i-1}} \cdot \left(\frac{PK_{i,t}}{PL_{i,t}}\right)^{\frac{1}{\rho_i-1}}.$$

Recall that: $\sigma_i = \frac{1}{1-\rho_i}$, which in turn implies:

$$\frac{QK_{i,t}}{QL_{i,t}} = \left(\frac{\alpha_i}{1-\alpha_i}\right)^{\sigma_i} \cdot \left(\frac{PL_{i,t}}{PK_{i,t}}\right)^{\sigma_i},$$

and, after logarithmic transformation:

$$\log\left(\frac{QK_{i,t}}{QL_{i,t}}\right) = \sigma_i \log\left(\frac{\alpha_i}{1-\alpha_i}\right) + \sigma_i \log\left(\frac{PL_{i,t}}{PK_{i,t}}\right).$$

Noteworthy, this equation implicitly assumes that prices (RHS) determine quantities (LHS) – not the inverse. However, this assumption may be justified due to price-taking assumption made in firm's optimisation problem (Mas-Colell et al., 1995).[23]

Analogical derivations have been performed for the remaining nests of the production function. Due to limited space, they are not shown here. Instead, Table 5 provides a concordance scheme between quantity and price variables used in the estimation process and corresponding substitution elasticities.

Table 5. Quantity and price variables used for estimation purposes in each of the production function nests

Nest	Quantity variables	Price variables
$\sigma_{top,i}$	$QI_{r,i,t}, QPKLE_{r,i,t}$	$PI_{r,i,t}, PKLE_{r,i,t}$
$\sigma_{armi,g}$	$QD_{r,g,t}, QM_{r,g,t}$	$PD_{r,g,t}, PM_{r,g,t}$
$\sigma_{kle,i}$	$QV_{r,i,t}, QE_{r,i,t}$	$PV_{r,i,t}, PE_{r,i,t}$
$\sigma_{va,i}$	$QK_{r,i,t}, QL_{r,i,t}$	$PK_{r,i,t}, PL_{r,i,t}$
$\sigma_{labu,i}$	$QLU_{r,i,t}, QLL_{r,i,t}$	$PLU_{r,i,t}, PLL_{r,i,t}$
$\sigma_{labl,i}$	$QLH_{r,i,t}, QLM_{r,i,t}$	$PLH_{r,i,t}, PLM_{r,i,t}$

Source: Own elaboration

Under the panel data framework applied in this study, there are separate equations estimated for each of the sectors, based on separate databases pooled over all countries and time periods. Therefore, for each activity sector the following relation could be estimated:

$$\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \sigma \log\left(\frac{\alpha_{r,t}}{1-\alpha_{r,t}}\right) + \sigma \log\left(\frac{PL_{r,t}}{PK_{r,t}}\right).$$

However, collinearity problems do arise with such an approach, since the relations of factor shares in a given country seem to be highly correlated with the relations of factor price indices in many cases. Still, these relations of factor shares are likely to differ between countries, offering a space for an introduction of constant terms with fixed effects into the model's specification.

[23] It is also of crucial importance not to use monetary values instead of quantities, since volume changes (LHS) need to be separated from price changes (RHS) – see Saito (2004). This has actually been done at the stage of preparing the database.

The application of the this methodology (i.e. pooling one dataset – over all countries and time slices – for each sector) implies that estimated elasticities are sector-specific and country uniform. In fact, this assumption is very common in empirical studies – see Koesler and Schymura (2012), Németh et al. (2011), Okagawa and Ban (2008). The elasticities have also been treated as equal over time, in line with all the mentioned studies. Koesler and Schymura (2012) argued that the panel data available in WIOD was too short in time dimension in order to properly account for time stability tests.

As previously indicated, a careful investigation of dynamic properties of the considered variables is essential in order to avoid obtaining spurious results. Therefore, the following stepwise procedure, derived from Fragiadakis et al. (2012), has been applied to each ratio of input quantities (LHS) and input prices (RHS) for all activity sectors and for all nests of production function.

In the first step, the stationarity of the data has been assessed, using combined Fisher/ADF panel unit root test. If both variables in a given equation (i.e. for a given sector-nest pair) turned out to be stationary, i.e. integrated of order zero, or I(0), the autoregressive distributed lag (ADL) model has been estimated, using Ordinary Least Squares (OLS):

$$\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \varphi_{0,r} + \varphi_1 t + \beta_1 \Delta\log\left(\frac{PL_{r,t}}{PK_{r,t}}\right) + \sum_{p=2}^{k} \beta_p \log\left(\frac{PL_{r,t+1-p}}{PK_{i,t+1-p}}\right) + \sum_{q=2}^{l} \gamma_q \log\left(\frac{QK_{r,t+1-q}}{QL_{i,t+1-q}}\right) + \varepsilon_{r,t}.$$ [24]

Short run elasticity equals β_1, while long-run elasticity equals $(\beta_1 + \sum_{p=2}^{k} \beta_p)/(1 - \sum_{q=2}^{l} \gamma_q)$.

If both variables turned out to be non-stationary, integrated of order one, i.e. I(1), Johansen- Fisher panel cointegration test has been applied in order to check for a cointegrating relationship between them. If this has been the case, the error correction model (ECM) has been estimated, using Fully-Modified Ordinary Least Squares (FMOLS):

$$\Delta\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \varphi_{0,r} + \varphi_1 t + \beta_1 \Delta\log\left(\frac{PL_{r,t}}{PK_{r,t}}\right) + \beta_2 \log\left(\frac{QK_{r,t-1}}{QL_{r,t-1}}\right) + \beta_3 \log\left(\frac{PL_{r,t-1}}{PK_{r,t-1}}\right) + \varepsilon_{r,t}.$$

Short run elasticity equals β_1, while long-run elasticity equals $-\beta_3/\beta_2$.

If the series turned out to be I(1), but not cointegrated or if their orders of integration occurred to be unequal, the model for differenced variables has been estimated, using Ordinary Least Squares (OLS):

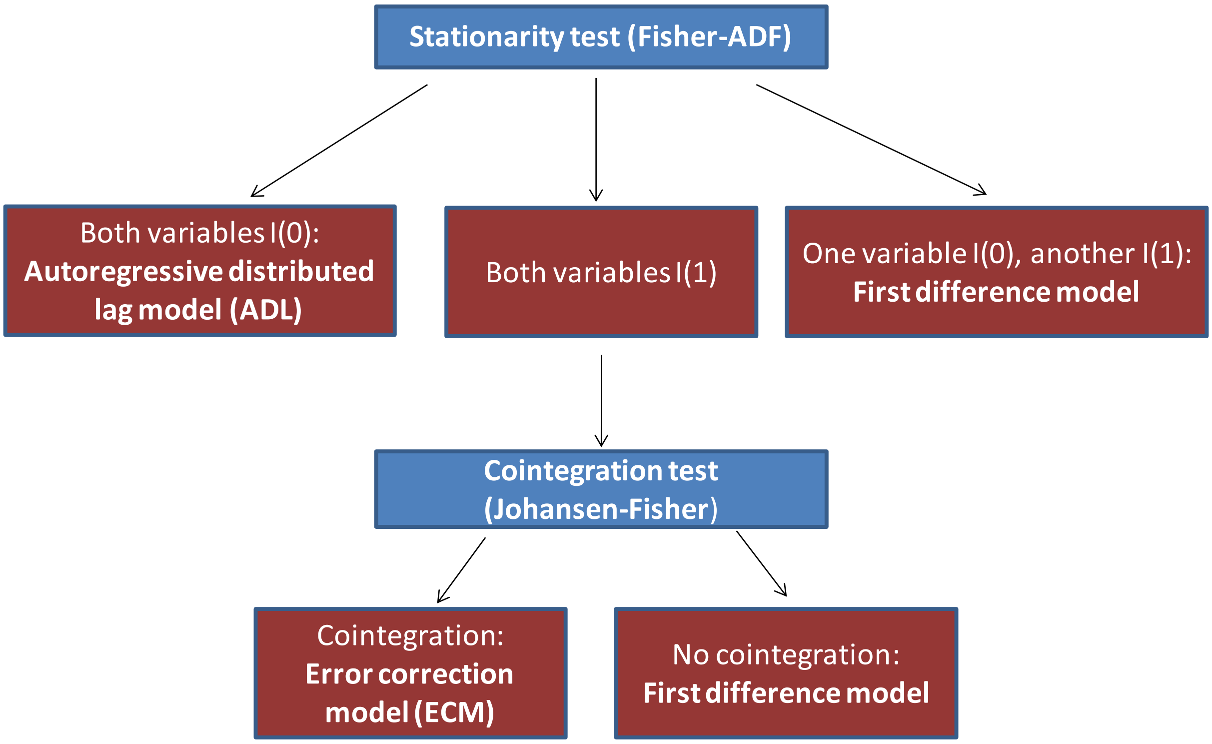
$$\Delta\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \beta_{0,r} + \beta_1 \Delta\log\left(\frac{PL_{r,t}}{PK_{r,t}}\right) + \varepsilon_{r,t}.$$

This specification yields only the short run elasticity, which equals β_1. Figure 3 provides a graphical representation of this stepwise procedure.[25]

[24] Note the presence of a country subscript r in the constant term. This captures the inclusion of fixed effect specification. The optimal lag orders for autoregressive (AR) and distributed lag (DL) components have been chosen based on Schwarz information criterion (SIC).

[25] While performing Fisher-ADF unit root test, it turned out that all of the analysed variables are at most integrated of order one, i.e. I(1). Hence, it was justified to stop the procedure outlined in Figure 3 after performing unit roots tests for first differences of those variables.

Figure 3. Steps in the estimation procedure



Source: Own elaboration based on Fragiadakis et al. (2012)

Notably, the inclusion of a time trend in the estimated model specifications (with an exception of differenced equations that do not capture long-term relationships) constitutes an attempt for a proper reflection of the technological progress, as well as a proxy for any other, country-uniform[26] factors (beyond input price ratio and lagged terms) that may determine the ratio of input volumes. In particular, too low/high elasticity estimates may result from over-/underestimation of productivity changes[27]. Moreover, Jalava et al. (2006) argued that the inclusion of a time variable enables also to control for potential estimation bias, stemming from misspecification of the type of technological change (i.e. TFP/Hicks-neutral vs. factor augmenting). This is of crucial importance, especially when the empirical foundations on a type of technological progress are lacking.[28]

[26] The country-specific factors are captured by constant terms with fixed effects.
[27] See Tipper (2012) for more discussion.
[28] Although van der Werf (2008) provided an explicit empirical evidence of the type of technical progress under CES framework, his estimates are related only to substitution possibilities between capital, labour and energy within the KLE nest.

It is also apparent that four model specifications may actually be estimated, taking into account various combinations of inversed ratios of input quantities and input prices:

$$\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \sigma\log\left(\frac{\alpha_{r,t}}{1-\alpha_{r,t}}\right) + \sigma\log\left(\frac{PL_{r,t}}{PK_{r,t}}\right); \qquad (1)$$

$$\log\left(\frac{QK_{r,t}}{QL_{r,t}}\right) = \sigma\log\left(\frac{\alpha_{r,t}}{1-\alpha_{r,t}}\right) - \sigma\log\left(\frac{PK_{r,t}}{PL_{r,t}}\right); \qquad (2)$$

$$\log\left(\frac{QL_{r,t}}{QK_{r,t}}\right) = \sigma\log\left(\frac{1-\alpha_{r,t}}{\alpha_{r,t}}\right) + \sigma\log\left(\frac{PK_{r,t}}{PL_{r,t}}\right); \qquad (3)$$

$$\log\left(\frac{QL_{r,t}}{QK_{r,t}}\right) = \sigma\log\left(\frac{1-\alpha_{r,t}}{\alpha_{r,t}}\right) - \sigma\log\left(\frac{PL_{r,t}}{PK_{r,t}}\right). \qquad (4)$$

In the following sections, these specifications, computed for all nests, are described as Option 1, Option 2, Option 3 and Option 4 respectively.[29] Regarding the ordering scheme for these options in production function nests other the one discussed above (i.e. value added nest with elasticity $\sigma_{va,i}$), the sequence of quantity and price variables appearing in nominators and denominators of the LHS and RHS ratio variables is coherent with the scheme shown in Table 5.

Basically, a parameter estimation for each of the previously described models (ADL, ECM, first difference model) yields the same elasticity values in all four options. However, it turns out that given dynamic properties (i.e. panel stationarity and cointegration) of quantity and price ratio variables, the use of their various combinations in various options may actually yield different elasticity estimates, provided that different "optimal" model specifications have been chosen in the stepwise procedure shown in Figure 3. Table 6 informs which type of model (ADL, ECM, first difference model) should actually be chosen for a given nest-sector combination under each of four equation specification options, based on the above mentioned algorithm highlighted.[30]

[29] It must be kept in mind that inverting the first RHS component of the sum has only a conventional meaning. In the estimation, this component is captured by a constant term with fixed effects.

[30] The results of combined Fisher/ADF panel unit root test and Johansen- Fisher panel cointegration test have not been reported due to the limited space of this paper. They remain available upon request.

Table 6. Type of "optimal" econometric model chosen under each of 4 options (i.e. equation specifications) for each sector-nest combination*

	σ(top)				σ(armi)				σ(kle)				σ(kl)				σ(labu)				σ(labl)			
	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4
agr	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ECM	diff	ADL	diff	diff	diff	diff	diff	diff	diff	diff	diff
atr	ECM	ECM	ECM	ECM	diff	ADL	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff
chm	ECM	ECM	ECM	ECM	diff	diff	ECM	ECM	diff	diff	diff	diff	ECM	diff	ADL	diff	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
com	diff	diff	ECM	ECM	ECM	ECM	diff	diff	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	ADL	ADL	diff	diff	ADL	ADL
con	diff	ECM	ECM	diff	ECM	ECM	diff	diff	ADL	diff	diff	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	diff	diff	ECM
edu	diff	diff	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	diff	diff	ECM	diff	diff	diff	diff	diff	diff	diff	diff
eeq	diff	ECM	ECM	diff	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ECM	ECM	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM
ele	ECM	ECM	ECM	ECM	diff	diff	ECM	ECM	ADL	diff	diff	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	ECM	diff	diff
fin	diff	diff	diff	diff	diff	diff	diff	diff	ECM	diff	diff	ECM	ECM	diff	ADL	diff	diff	diff	diff	diff	diff	diff	diff	diff
foo	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	diff	diff	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	diff	diff
hea	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
htl	ADL	diff	ECM	diff	diff	diff	diff	diff	ADL	diff	diff	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff	diff	diff	diff	diff
lea	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	ECM	ECM	ECM
ltr	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	diff	diff	diff	diff	diff	diff
mch	diff	diff	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM	ECM	diff	ADL	diff	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
min	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	ECM	ECM	diff	diff	diff	diff	diff	diff	ADL	ADL	diff	diff	diff	diff
mtl	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	ECM	ECM	ECM
mvh	ADL	ADL	ADL	ADL	diff	diff	diff	diff	diff	diff	diff	diff	diff	ADL	ADL	diff	diff	diff	ADL	ADL	diff	diff	diff	diff
nmm	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	diff	diff	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	ECM	ECM	ECM
oth	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	diff	diff	ECM	ECM	ECM	ECM
pet	ADL	ADL	ADL	ADL	diff	diff	diff	diff	ECM	ECM	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM
ppp	ADL	diff	diff	ADL	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM
pub	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	diff	diff	diff	diff	ECM	ECM	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM
rea	diff	diff	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM	diff	ADL	diff	ECM	diff	diff	ADL	ADL	diff	diff	diff	diff
ren	ADL	diff	diff	ADL	ECM	ECM	diff	diff	diff	ECM	ECM	diff	diff	diff	ADL	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff
rub	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	diff	diff	ECM	ECM	diff	diff	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
srv	diff	diff	ECM	ECM	ECM	ECM	diff	diff	ADL	diff	diff	ADL	diff	diff	ADL	ADL	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
teq	diff	diff	diff	diff	diff	diff	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ADL	ADL	diff	diff	ADL	ADL	ECM	ECM	ECM	ECM
tex	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM	ECM	diff	diff	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM
trd	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff	ADL	ADL	diff	diff	diff	diff
trv	diff	diff	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	diff	ADL	diff	diff	diff	diff	diff	diff	diff	diff	diff
whs	diff	ADL	ADL	diff	ECM	ECM	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	ADL	ADL	diff	diff	ADL	ADL	diff	diff	diff	diff
woo	ADL	ADL	diff	diff	diff	diff	diff	diff	ECM	ECM	diff	diff	ECM	diff	diff	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM
wtr	ECM	ECM	ECM	ECM	diff	diff	diff	diff	ECM	ECM	ECM	ECM	ECM	ECM	diff	diff	diff	diff	diff	diff	diff	diff	diff	diff

**"ADL" stands for Autoregressive Distributed Model, "ECM" stands for Error Correction Model, "diff" stands for model for first differences.*

Source: Own elaboration

6. Estimation results

Tables 7-12 contain estimated values of short- and long-run substitution elasticities for each of 6 nests of production function and for each of 34 sectors. Since the issue of which of 4 specification options should be used in the stepwise procedure highlighted in Figure 3 seems to be an unsolvable dispute, all 3 econometric models have actually been estimated for all 34 sectors in all 6 nests. This in fact generated as much as 34×6×5 = 1020 point estimates of substitution elasticities.

Notably, the unrestricted econometric estimation might actually generate negative estimates of elasticity values and thus create interpretation problems in single cases. However, such negative estimates may be perceived as indicating zero substitution (i.e. Leontief specification) between input factors (Prywes, 1986). Such an approach has also been undertaken in this study.

Substitution elasticities at the top nest, i.e. between aggregate materials and capital-labour-energy composite, are located between zero (Leontief specification) and unity (Cobb-Douglas specification) in all but a few of the cases (see Table 7). There is also one slightly negative estimate: for long-term elasticity in *Transport equipment* (teq), derived from Error Correction Model (ECM). Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are higher than their short-run counterparts in 25 and 24 out of 34 activity sectors respectively. On average, long-term elasticity estimates obtained from ECMs (0.69) tend also to be slightly higher than those obtained from ADLs (0.60). Standard deviations of long-term values under ADLs and ECMs amount to 0.31 and 0.48 respectively. Variation coefficients (standard deviations divided by averages) account for 51% and 69% respectively. Hence, there is also huge heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from 0.09 in *Transport equipment* (teq) to 1.32 in *Air transport* (atr), while for ECMs – from technically zero in *Transport equipment* (teq) to 2.07 in *Real estate activities* (rea).

Table 7. Econometric estimates of substitution elasticities between aggregate materials and capital-labour-energy composite – top nest: σ(top)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	0.31	(0.05)	0.19	(0.11)	0.33	(0.04)	0.20	(0.20)	0.34	(0.05)	NA	NA
atr	0.77	(0.07)	1.32	(0.15)	1.04	(0.06)	1.24	(0.14)	1.14	(0.07)	NA	NA
chm	0.38	(0.07)	0.44	(0.08)	0.40	(0.06)	0.40	(0.13)	0.30	(0.07)	NA	NA
com	0.51	(0.10)	0.62	(0.18)	0.52	(0.08)	0.86	(0.30)	0.51	(0.12)	NA	NA
con	0.35	(0.05)	0.34	(0.13)	0.34	(0.04)	0.26	(0.19)	0.34	(0.05)	NA	NA
edu	0.43	(0.09)	0.84	(0.17)	0.50	(0.08)	0.85	(0.20)	0.41	(0.09)	NA	NA
eeq	0.13	(0.11)	0.64	(0.22)	0.14	(0.10)	0.56	(0.25)	0.15	(0.11)	NA	NA
ele	0.02	(0.08)	0.18	(0.19)	0.07	(0.07)	0.00	(0.26)	0.01	(0.08)	NA	NA
fin	0.29	(0.08)	0.74	(0.14)	0.29	(0.06)	0.80	(0.20)	0.22	(0.08)	NA	NA
foo	0.41	(0.06)	0.38	(0.08)	0.39	(0.05)	0.37	(0.10)	0.39	(0.06)	NA	NA
hea	0.43	(0.10)	0.75	(0.20)	0.48	(0.09)	0.81	(0.47)	0.37	(0.10)	NA	NA
htl	0.58	(0.07)	1.09	(0.21)	0.53	(0.06)	1.37	(0.33)	0.42	(0.06)	NA	NA
lea	0.51	(0.09)	0.76	(0.23)	0.51	(0.08)	0.58	(0.31)	0.52	(0.10)	NA	NA
ltr	0.38	(0.06)	0.25	(0.12)	0.41	(0.05)	0.37	(0.18)	0.37	(0.06)	NA	NA
mch	0.62	(0.07)	1.05	(0.20)	0.67	(0.06)	1.75	(0.70)	0.54	(0.07)	NA	NA
min	0.26	(0.06)	0.80	(0.13)	0.24	(0.05)	0.90	(0.27)	0.18	(0.06)	NA	NA
mtl	0.36	(0.06)	0.55	(0.15)	0.37	(0.05)	0.33	(0.26)	0.32	(0.06)	NA	NA
mvh	0.54	(0.07)	0.92	(0.12)	0.53	(0.06)	1.25	(0.23)	0.40	(0.07)	NA	NA
nmm	0.27	(0.06)	0.62	(0.12)	0.26	(0.05)	0.63	(0.24)	0.21	(0.06)	NA	NA
oth	0.76	(0.04)	0.92	(0.08)	0.76	(0.03)	1.03	(0.17)	0.73	(0.04)	NA	NA
pet	0.13	(0.08)	0.39	(0.19)	0.07	(0.07)	0.43	(0.38)	0.02	(0.08)	NA	NA
ppp	0.43	(0.06)	0.32	(0.10)	0.44	(0.05)	0.49	(0.12)	0.43	(0.06)	NA	NA
pub	0.36	(0.10)	1.03	(0.25)	0.36	(0.08)	1.04	(0.39)	0.26	(0.10)	NA	NA
rea	0.28	(0.07)	0.89	(0.43)	0.28	(0.06)	2.07	(1.43)	0.29	(0.07)	NA	NA
ren	0.54	(0.11)	0.85	(0.29)	0.56	(0.08)	0.86	(0.31)	0.52	(0.10)	NA	NA
rub	0.27	(0.06)	0.36	(0.10)	0.26	(0.06)	0.34	(0.25)	0.21	(0.06)	NA	NA
srv	0.67	(0.05)	0.71	(0.07)	0.67	(0.05)	0.67	(0.14)	0.67	(0.06)	NA	NA
teq	0.51	(0.07)	0.09	(0.18)	0.56	(0.07)	-0.10	(0.25)	0.61	(0.08)	NA	NA
tex	0.21	(0.08)	0.25	(0.10)	0.21	(0.07)	0.29	(0.20)	0.23	(0.08)	NA	NA
trd	0.66	(0.07)	0.41	(0.17)	0.68	(0.06)	0.47	(0.43)	0.68	(0.07)	NA	NA
trv	0.62	(0.09)	0.68	(0.22)	0.64	(0.08)	1.18	(0.56)	0.58	(0.09)	NA	NA
whs	0.59	(0.06)	0.45	(0.10)	0.61	(0.05)	0.59	(0.15)	0.61	(0.06)	NA	NA
woo	0.31	(0.06)	0.41	(0.13)	0.29	(0.05)	0.37	(0.30)	0.28	(0.06)	NA	NA
wtr	0.40	(0.05)	0.20	(0.13)	0.42	(0.05)	0.18	(0.19)	0.44	(0.05)	NA	NA

Source: Own elaboration

Substitution elasticities at the Armington nest, i.e. between domestic and imported materials, are in general located around unity, with two visible outliers – long-term elasticities for *Water transport* (wtr) derived from both ADL and ECM (see Table 8). Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are both higher than their short-run counterparts for 19 out of 34 products. On average (and after excluding the identified outliers), long-term elasticity estimates obtained from ECMs (0.96) tend also to be slightly higher than those obtained from ADLs (0.93). Standard deviations of long-term values under ADLs and ECMs both amount to 0.35. Variation coefficients (standard deviations divided by averages) account for 37% and 36% respectively. Hence, there is also huge heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from 0.24 in *Hotels and restaurants* (htl) to 1.85 in *Real estate activities* (rea), while for ECMs – from 0.22 in *Air transport* (atr) to 1.68 in *Coke, refined petroleum and nuclear fuel, industrial gas* (pet).

Table 8. Econometric estimates of substitution elasticities between domestic and imported materials – Armington nest: σ(armi)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	0.89	(0.11)	0.68	(0.15)	0.90	(0.09)	0.80	(0.23)	1.00	(0.11)	NA	NA
atr	0.52	(0.25)	0.46	(0.31)	0.52	(0.23)	0.22	(0.42)	0.74	(0.26)	NA	NA
chm	1.10	(0.16)	1.15	(0.25)	1.09	(0.13)	1.38	(0.46)	1.04	(0.16)	NA	NA
com	1.00	(0.10)	0.96	(0.13)	0.92	(0.09)	0.98	(0.20)	1.12	(0.11)	NA	NA
con	1.19	(0.23)	0.73	(0.23)	1.13	(0.17)	0.95	(0.21)	1.17	(0.24)	NA	NA
edu	0.75	(0.32)	1.34	(0.36)	1.19	(0.24)	1.58	(0.53)	1.17	(0.29)	NA	NA
eeq	0.86	(0.24)	0.29	(0.33)	0.95	(0.18)	0.58	(0.42)	0.97	(0.25)	NA	NA
ele	1.11	(0.18)	0.92	(0.28)	0.96	(0.15)	0.79	(0.43)	1.16	(0.17)	NA	NA
fin	0.66	(0.15)	0.77	(0.32)	0.72	(0.12)	1.14	(0.47)	0.65	(0.15)	NA	NA
foo	0.92	(0.09)	0.66	(0.13)	0.95	(0.08)	0.77	(0.17)	0.96	(0.10)	NA	NA
hea	0.93	(0.24)	0.76	(0.41)	1.00	(0.23)	1.06	(0.80)	1.18	(0.25)	NA	NA
htl	1.15	(0.47)	0.24	(0.70)	1.29	(0.38)	0.48	(0.80)	0.96	(0.46)	NA	NA
lea	1.80	(0.39)	1.03	(0.61)	1.83	(0.34)	0.98	(1.01)	1.86	(0.41)	NA	NA
ltr	0.47	(0.20)	0.95	(0.45)	0.40	(0.16)	0.58	(0.69)	0.39	(0.19)	NA	NA
mch	0.78	(0.20)	0.98	(0.21)	0.82	(0.17)	0.86	(0.28)	1.05	(0.22)	NA	NA
min	0.43	(0.14)	0.51	(0.18)	0.40	(0.13)	0.47	(0.27)	0.42	(0.15)	NA	NA
mtl	0.84	(0.11)	1.54	(0.20)	0.93	(0.10)	1.65	(0.30)	1.01	(0.12)	NA	NA
mvh	0.58	(0.21)	0.62	(0.33)	0.56	(0.19)	0.67	(0.54)	0.64	(0.22)	NA	NA
nmm	1.08	(0.10)	0.90	(0.24)	1.22	(0.10)	0.93	(0.25)	1.20	(0.11)	NA	NA
oth	1.19	(0.19)	1.22	(0.40)	1.30	(0.16)	0.74	(0.73)	1.32	(0.19)	NA	NA
pet	0.92	(0.13)	1.33	(0.21)	0.96	(0.10)	1.68	(0.34)	0.88	(0.14)	NA	NA
ppp	1.17	(0.10)	0.84	(0.30)	1.04	(0.08)	0.96	(0.30)	1.05	(0.10)	NA	NA
pub	0.92	(0.26)	1.25	(0.22)	0.99	(0.22)	1.09	(0.40)	0.69	(0.28)	NA	NA
rea	0.40	(0.42)	1.85	(0.61)	0.33	(0.32)	1.47	(0.79)	0.68	(0.39)	NA	NA
ren	1.06	(0.11)	0.78	(0.17)	1.07	(0.08)	1.08	(0.25)	1.04	(0.10)	NA	NA
rub	1.21	(0.18)	1.09	(0.24)	1.23	(0.14)	1.11	(0.29)	1.26	(0.19)	NA	NA
srv	1.09	(0.15)	1.28	(0.25)	1.02	(0.13)	1.34	(0.43)	0.92	(0.16)	NA	NA
teq	0.95	(0.25)	1.21	(0.32)	0.93	(0.23)	0.81	(0.45)	1.00	(0.27)	NA	NA
tex	0.56	(0.25)	0.64	(0.32)	0.63	(0.21)	0.62	(0.45)	0.67	(0.28)	NA	NA
trd	0.82	(0.16)	0.93	(0.22)	0.76	(0.14)	0.98	(0.35)	0.86	(0.17)	NA	NA
trv	0.46	(0.25)	0.95	(0.53)	0.25	(0.19)	1.05	(0.67)	0.43	(0.24)	NA	NA
whs	0.45	(0.14)	1.19	(0.25)	0.36	(0.13)	1.20	(0.48)	0.34	(0.14)	NA	NA
woo	0.97	(0.10)	0.77	(0.24)	0.87	(0.09)	0.76	(0.50)	0.92	(0.10)	NA	NA
wtr	0.26	(0.61)	2.84	(1.64)	0.69	(0.58)	26.17	(88.79)	0.08	(0.58)	NA	NA

Source: Own elaboration

Substitution elasticities at the capital-labour-energy nest, i.e. between value added and energy, are situated between zero and unity in almost all of the cases (see Table 9). There are also 14 slightly negative estimates (both in short- and long-term) – most of them are long-run estimates obtained either from ADLs or from ECMs. Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are higher than their short-run counterparts in 23 and 29 out of 34 activity sectors respectively. On average, long-term elasticity estimates obtained from ECMs (0.56) tend also to be higher than those obtained from ADLs (0.40). Standard deviations of long-term values under ADLs and ECMs amount to 0.34 and 0.43 respectively. Variation coefficients (standard deviations divided by averages) account for 84% and 76% respectively. Hence, there is also huge heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from technically zero in *Construction* (con) to 1.17 in *Leather, leather and footwear* (lea), while for ECMs – from technically zero in *Mining and quarrying* (min) to 1.60 in *Machinery, nec* (mch).

Table 9. Econometric estimates of substitution elasticities between value added and energy – capital-labour-energy nest: σ(kle)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	0.22	(0.05)	0.56	(0.19)	0.21	(0.04)	0.77	(0.28)	0.18	(0.05)	NA	NA
atr	0.30	(0.13)	0.88	(0.28)	0.32	(0.11)	1.06	(0.46)	0.27	(0.14)	NA	NA
chm	0.08	(0.05)	0.20	(0.17)	0.07	(0.05)	0.28	(0.35)	0.05	(0.05)	NA	NA
com	0.17	(0.08)	-0.05	(0.24)	0.17	(0.06)	-0.09	(0.36)	0.22	(0.07)	NA	NA
con	-0.05	(0.06)	-0.20	(0.19)	-0.03	(0.06)	-0.05	(0.29)	-0.03	(0.06)	NA	NA
edu	0.07	(0.06)	0.31	(0.19)	0.06	(0.05)	0.56	(0.25)	0.01	(0.06)	NA	NA
eeq	0.24	(0.08)	0.73	(0.17)	0.26	(0.06)	0.84	(0.28)	0.14	(0.08)	NA	NA
ele	0.14	(0.05)	-0.02	(0.09)	0.17	(0.04)	-0.05	(0.13)	0.19	(0.05)	NA	NA
fin	0.00	(0.07)	-0.01	(0.17)	0.08	(0.06)	0.16	(0.22)	0.03	(0.08)	NA	NA
foo	0.28	(0.05)	0.58	(0.12)	0.28	(0.04)	0.63	(0.16)	0.25	(0.05)	NA	NA
hea	0.12	(0.05)	0.43	(0.12)	0.13	(0.04)	0.54	(0.17)	0.05	(0.05)	NA	NA
htl	0.12	(0.06)	0.47	(0.15)	0.14	(0.05)	0.92	(0.32)	0.06	(0.06)	NA	NA
lea	0.46	(0.11)	1.17	(0.26)	0.44	(0.10)	1.19	(0.57)	0.34	(0.11)	NA	NA
ltr	0.21	(0.04)	0.61	(0.21)	0.18	(0.04)	0.41	(0.31)	0.16	(0.04)	NA	NA
mch	0.35	(0.07)	1.08	(0.28)	0.35	(0.06)	1.60	(0.54)	0.25	(0.07)	NA	NA
min	0.19	(0.08)	-0.05	(0.19)	0.21	(0.07)	-0.31	(0.41)	0.17	(0.08)	NA	NA
mtl	0.16	(0.07)	0.16	(0.19)	0.16	(0.06)	0.18	(0.28)	0.14	(0.07)	NA	NA
mvh	0.30	(0.09)	0.48	(0.25)	0.33	(0.08)	0.70	(0.38)	0.30	(0.09)	NA	NA
nmm	0.10	(0.05)	0.48	(0.17)	0.15	(0.05)	0.92	(0.39)	0.06	(0.06)	NA	NA
oth	0.31	(0.10)	0.82	(0.35)	0.29	(0.09)	1.00	(0.69)	0.26	(0.10)	NA	NA
pet	0.42	(0.05)	0.40	(0.14)	0.50	(0.04)	0.62	(0.34)	0.52	(0.05)	NA	NA
ppp	0.13	(0.06)	0.40	(0.14)	0.15	(0.06)	0.87	(0.45)	0.16	(0.06)	NA	NA
pub	0.09	(0.05)	0.12	(0.14)	0.09	(0.04)	0.26	(0.19)	0.07	(0.05)	NA	NA
rea	0.01	(0.07)	-0.02	(0.17)	0.04	(0.05)	0.11	(0.24)	0.04	(0.06)	NA	NA
ren	0.19	(0.08)	0.07	(0.23)	0.21	(0.06)	0.30	(0.44)	0.20	(0.07)	NA	NA
rub	0.15	(0.08)	0.50	(0.28)	0.19	(0.07)	0.75	(0.49)	0.13	(0.08)	NA	NA
srv	0.10	(0.05)	0.37	(0.13)	0.11	(0.05)	0.44	(0.19)	0.08	(0.05)	NA	NA
teq	0.23	(0.07)	0.36	(0.18)	0.29	(0.06)	0.37	(0.23)	0.23	(0.07)	NA	NA
tex	0.22	(0.07)	0.62	(0.22)	0.22	(0.06)	0.93	(0.41)	0.21	(0.06)	NA	NA
trd	0.10	(0.05)	0.15	(0.19)	0.16	(0.05)	0.44	(0.34)	0.10	(0.06)	NA	NA
trv	0.45	(0.08)	0.39	(0.25)	0.44	(0.07)	0.61	(0.48)	0.45	(0.08)	NA	NA
whs	0.15	(0.08)	0.60	(0.28)	0.17	(0.07)	1.07	(0.49)	0.09	(0.09)	NA	NA
woo	0.10	(0.07)	0.09	(0.24)	0.13	(0.06)	0.07	(0.41)	0.14	(0.07)	NA	NA
wtr	0.22	(0.15)	0.82	(0.21)	0.28	(0.11)	0.92	(0.30)	0.14	(0.16)	NA	NA

Source: Own elaboration

Substitution elasticities at the value added nest, i.e. between capital and labour, are situated between zero and unity practically in all of the cases (see Table 10). However, their values are remarkably lower than at the upper nests of production functions, discussed previously. There are also 12 slightly negative estimates (both in short- and long-term) – most of them are long-run estimates obtained from ADLs and ECMs. Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are higher than their short-run counterparts in 30 and 28 out of 34 activity sectors respectively. On average, long-term elasticity estimates obtained from ECMs (0.24) tend also to be higher than those obtained from ADLs (0.18). Standard deviations of long-term values under ADLs and ECMs amount to 0.16 and 0.22 respectively. Variation coefficients (standard deviations divided by averages) account for 89% and 90% respectively. Hence, there is also quite large heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from technically zero in *Real estate activities* (rea) to 0.55 in *Machinery, nec* (mch), while for ECMs – from technically zero in *Education* (edu) to 0.82 in *Water transport* (wtr).

Table 10. Econometric estimates of substitution elasticities between capital and labour – value added nest: σ(va)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	0.01	(0.01)	0.06	(0.06)	0.01	(0.01)	0.08	(0.08)	0.01	(0.01)	NA	NA
atr	0.15	(0.03)	-0.02	(0.08)	0.14	(0.02)	-0.08	(0.08)	0.17	(0.02)	NA	NA
chm	0.16	(0.02)	0.42	(0.11)	0.15	(0.02)	0.52	(0.20)	0.15	(0.02)	NA	NA
com	0.05	(0.01)	0.22	(0.04)	0.08	(0.01)	0.24	(0.05)	0.08	(0.02)	NA	NA
con	0.05	(0.01)	0.14	(0.04)	0.03	(0.01)	0.01	(0.07)	0.03	(0.01)	NA	NA
edu	0.02	(0.01)	-0.09	(0.11)	0.02	(0.01)	-0.10	(0.22)	0.02	(0.01)	NA	NA
eeq	0.05	(0.01)	0.16	(0.07)	0.05	(0.01)	0.29	(0.20)	0.05	(0.01)	NA	NA
ele	0.16	(0.03)	0.34	(0.11)	0.16	(0.02)	0.23	(0.24)	0.14	(0.02)	NA	NA
fin	0.04	(0.01)	0.15	(0.07)	0.08	(0.01)	0.27	(0.13)	0.06	(0.01)	NA	NA
foo	0.08	(0.02)	0.43	(0.11)	0.06	(0.02)	0.54	(0.34)	0.06	(0.02)	NA	NA
hea	0.01	(0.01)	0.02	(0.05)	0.01	(0.01)	0.00	(0.06)	0.02	(0.01)	NA	NA
htl	0.01	(0.01)	0.05	(0.04)	0.01	(0.01)	0.06	(0.05)	0.01	(0.01)	NA	NA
lea	-0.02	(0.01)	0.07	(0.08)	-0.01	(0.01)	0.38	(0.28)	-0.03	(0.01)	NA	NA
ltr	0.02	(0.01)	0.19	(0.06)	0.02	(0.01)	0.23	(0.11)	0.01	(0.01)	NA	NA
mch	0.12	(0.02)	0.55	(0.12)	0.13	(0.02)	0.62	(0.20)	0.08	(0.02)	NA	NA
min	0.05	(0.01)	0.18	(0.08)	0.05	(0.01)	0.52	(0.36)	0.04	(0.01)	NA	NA
mtl	0.11	(0.02)	0.24	(0.04)	0.11	(0.01)	0.20	(0.05)	0.10	(0.02)	NA	NA
mvh	0.09	(0.02)	0.32	(0.08)	0.09	(0.02)	0.35	(0.19)	0.07	(0.02)	NA	NA
nmm	0.18	(0.03)	0.40	(0.11)	0.17	(0.02)	0.44	(0.11)	0.13	(0.02)	NA	NA
oth	0.03	(0.01)	0.22	(0.05)	0.03	(0.01)	0.24	(0.06)	0.02	(0.01)	NA	NA
pet	0.05	(0.02)	0.35	(0.16)	0.04	(0.01)	0.40	(0.72)	0.03	(0.01)	NA	NA
ppp	0.14	(0.02)	0.19	(0.09)	0.14	(0.02)	0.23	(0.16)	0.13	(0.02)	NA	NA
pub	0.01	(0.01)	0.06	(0.08)	0.01	(0.01)	0.02	(0.14)	0.01	(0.01)	NA	NA
rea	0.24	(0.05)	-0.14	(0.18)	0.22	(0.04)	-0.05	(0.24)	0.20	(0.04)	NA	NA
ren	0.04	(0.01)	0.37	(0.09)	0.07	(0.02)	0.53	(0.12)	0.03	(0.02)	NA	NA
rub	0.23	(0.03)	0.27	(0.07)	0.24	(0.03)	0.40	(0.12)	0.27	(0.03)	NA	NA
srv	0.00	(0.01)	-0.02	(0.08)	0.01	(0.01)	0.00	(0.12)	0.01	(0.01)	NA	NA
teq	0.04	(0.01)	0.06	(0.05)	0.05	(0.01)	0.12	(0.07)	0.05	(0.01)	NA	NA
tex	0.02	(0.01)	0.08	(0.04)	0.02	(0.01)	0.19	(0.07)	0.01	(0.01)	NA	NA
trd	0.01	(0.01)	0.02	(0.06)	0.01	(0.01)	0.03	(0.08)	0.01	(0.01)	NA	NA
trv	0.02	(0.01)	0.18	(0.06)	0.02	(0.01)	0.27	(0.11)	0.00	(0.01)	NA	NA
whs	0.05	(0.02)	0.23	(0.08)	0.02	(0.02)	0.10	(0.16)	0.02	(0.02)	NA	NA
woo	0.09	(0.01)	0.13	(0.05)	0.10	(0.01)	0.19	(0.11)	0.08	(0.01)	NA	NA
wtr	0.08	(0.02)	0.17	(0.15)	0.08	(0.02)	0.82	(1.19)	0.06	(0.02)	NA	NA

Source: Own elaboration

Estimates of substitution elasticities at the upper labour nest, i.e. between upper- and low-skilled labour, turned out to be much less conclusive than in case of the previously discussed, non-labour nests (see Table 11). There are numerous (namely 57, 53 of which in the short-term) cases where obtained point estimates are negative, but many of them cannot be described as "technically close to zero". In the "non-negative cases", short-run estimates are still relatively low, in contrast to long-run elasticity values. Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are both higher than their short-run counterparts in 31 out of 34 activity sectors respectively. On average, long-term elasticity estimates obtained from ECMs (0.64) tend also to be much higher than those obtained from ADLs (0.40). Standard deviations of long-term values under ADLs and ECMs amount to 0.32 and 0.51 respectively. Variation coefficients (standard deviations divided by averages) both account for as much as 80%. Therefore, there is also huge heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from -0.50 in *Other community, social and personal services* (srv) to

1.04 in *Electricity, gas and water supply* (ele), while for ECMs – from -0.75 in *Other community, social and personal services* (srv) to 1.48 in *Food, beverages and tobacco* (foo).

Table 11. Econometric estimates of substitution elasticities between upper- and low-skilled labour – upper labour nest: σ(labu)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	0.01	(0.08)	0.54	(0.34)	0.00	(0.06)	0.81	(0.49)	-0.06	(0.07)	NA	NA
atr	-0.02	(0.05)	0.09	(0.13)	-0.03	(0.04)	0.09	(0.19)	-0.04	(0.05)	NA	NA
chm	0.09	(0.07)	0.31	(0.23)	0.09	(0.06)	0.44	(0.33)	0.05	(0.06)	NA	NA
com	0.28	(0.10)	0.40	(0.26)	0.28	(0.08)	0.51	(0.34)	0.23	(0.09)	NA	NA
con	0.01	(0.07)	0.49	(0.39)	-0.01	(0.06)	0.72	(0.67)	-0.04	(0.06)	NA	NA
edu	0.15	(0.08)	0.71	(0.39)	0.16	(0.07)	0.90	(0.58)	0.11	(0.07)	NA	NA
eeq	0.11	(0.06)	0.36	(0.24)	0.09	(0.05)	0.30	(0.30)	0.08	(0.05)	NA	NA
ele	0.08	(0.12)	1.04	(0.35)	0.07	(0.10)	1.21	(0.41)	-0.12	(0.11)	NA	NA
fin	0.23	(0.10)	0.18	(0.27)	0.21	(0.08)	0.19	(0.46)	0.24	(0.09)	NA	NA
foo	0.04	(0.04)	0.90	(0.33)	0.03	(0.04)	1.48	(0.62)	-0.04	(0.04)	NA	NA
hea	-0.02	(0.07)	0.45	(0.32)	-0.01	(0.06)	1.40	(0.82)	-0.08	(0.07)	NA	NA
htl	-0.16	(0.07)	0.56	(0.67)	-0.17	(0.05)	0.55	(1.05)	-0.21	(0.06)	NA	NA
lea	0.01	(0.05)	0.80	(0.32)	0.00	(0.04)	1.17	(0.47)	-0.07	(0.04)	NA	NA
ltr	-0.02	(0.07)	0.22	(0.31)	-0.01	(0.05)	0.45	(0.58)	-0.06	(0.06)	NA	NA
mch	-0.06	(0.05)	0.33	(0.21)	-0.07	(0.05)	1.10	(0.59)	-0.13	(0.05)	NA	NA
min	0.02	(0.11)	0.11	(0.27)	0.02	(0.10)	0.14	(0.33)	-0.04	(0.11)	NA	NA
mtl	-0.01	(0.04)	0.60	(0.29)	-0.01	(0.03)	1.04	(0.49)	-0.07	(0.03)	NA	NA
mvh	0.02	(0.05)	0.34	(0.35)	0.01	(0.05)	0.86	(0.85)	-0.01	(0.04)	NA	NA
nmm	0.05	(0.05)	0.44	(0.24)	0.05	(0.04)	0.79	(0.42)	-0.01	(0.04)	NA	NA
oth	0.09	(0.05)	0.77	(0.24)	0.08	(0.04)	1.32	(0.51)	0.00	(0.04)	NA	NA
pet	-0.22	(0.13)	0.20	(0.21)	-0.20	(0.12)	0.25	(0.24)	-0.24	(0.13)	NA	NA
ppp	0.02	(0.05)	0.37	(0.26)	0.04	(0.05)	0.84	(0.40)	-0.02	(0.04)	NA	NA
pub	0.04	(0.10)	-0.33	(0.37)	0.04	(0.08)	-0.47	(0.70)	0.10	(0.08)	NA	NA
rea	0.11	(0.06)	0.59	(0.21)	0.09	(0.05)	0.72	(0.27)	0.03	(0.06)	NA	NA
ren	0.03	(0.06)	0.24	(0.27)	0.01	(0.05)	0.12	(0.44)	0.02	(0.05)	NA	NA
rub	0.03	(0.05)	0.47	(0.23)	0.02	(0.04)	0.85	(0.43)	-0.04	(0.04)	NA	NA
srv	-0.05	(0.08)	-0.50	(0.29)	-0.05	(0.06)	-0.75	(0.50)	0.02	(0.07)	NA	NA
teq	0.08	(0.05)	0.67	(0.22)	0.06	(0.04)	1.06	(0.39)	0.01	(0.04)	NA	NA
tex	0.01	(0.05)	0.74	(0.31)	0.00	(0.04)	1.03	(0.46)	-0.06	(0.04)	NA	NA
trd	-0.01	(0.05)	0.41	(0.40)	-0.02	(0.04)	0.98	(0.94)	-0.05	(0.04)	NA	NA
trv	-0.04	(0.08)	0.08	(0.34)	-0.03	(0.07)	0.07	(0.64)	-0.06	(0.07)	NA	NA
whs	-0.01	(0.05)	0.25	(0.36)	-0.01	(0.04)	0.65	(0.80)	-0.04	(0.04)	NA	NA
woo	0.00	(0.04)	0.66	(0.28)	-0.01	(0.03)	0.67	(0.36)	-0.05	(0.04)	NA	NA
wtr	-0.06	(0.07)	0.11	(0.31)	-0.07	(0.06)	0.16	(0.45)	-0.09	(0.06)	NA	NA

Source: Own elaboration

Similarly to the upper labour nest, estimates of substitution elasticities at the lower labour nest, i.e. between high- and medium-skilled labour, also turned out to be much less conclusive than in case of the previously discussed, non-labour nests (see Table 12). There are numerous (namely 60, 50 of which in the short-term) cases where obtained point estimates are negative, but many of them cannot be described as “technically close to zero”. In the “non-negative cases”, short-term estimates are still relatively low, in contrast tp long-run elasticity values. Long-term elasticities (suitable for CGE models) derived from Autoregressive Distributed Lag models (ADLs) and Error Correction Models (ECMs) are higher than their short-run counterparts in 30 and 28 out of 34 activity sectors respectively. On average, long-term elasticity estimates obtained from ECMs (0.31) tend also to be much higher than those obtained from ADLs (0.27). Standard deviations of long-term values under ADLs and ECMs amount to 0.37 and 0.44 respectively. Variation coefficients (standard deviations divided by averages) account for as much as 136% and 140% respectively. Therefore, there is also huge heterogeneity of elasticity estimates across sectors. For ADLs, estimated values range from -1.25 in *Construction* (con) to 0.94 in *Electricity, gas and water supply* (ele), while for ECMs – from -1.44 in *Construction* (con) to 1.03 in *Electricity, gas and water supply* (ele).

Table 12. Econometric estimates of substitution elasticities between high- and medium-skilled labour – lower labour nest: σ(labl)

	ADL				ECM				difference equation			
	short-term		long-term		short-term		long-term		short-term		long-term	
agr	-0.14	(0.13)	0.16	(0.40)	-0.15	(0.11)	0.34	(0.83)	-0.19	(0.12)	NA	NA
atr	-0.07	(0.12)	-0.03	(0.41)	-0.11	(0.11)	0.16	(0.91)	-0.07	(0.12)	NA	NA
chm	0.08	(0.11)	0.59	(0.26)	0.05	(0.09)	0.59	(0.47)	0.02	(0.11)	NA	NA
com	-0.17	(0.14)	0.02	(0.47)	-0.08	(0.11)	0.14	(0.77)	-0.09	(0.13)	NA	NA
con	-0.37	(0.16)	-1.25	(0.52)	-0.35	(0.13)	-1.44	(0.77)	-0.27	(0.16)	NA	NA
edu	0.22	(0.09)	0.28	(0.28)	0.24	(0.07)	0.33	(0.40)	0.22	(0.09)	NA	NA
eeq	0.07	(0.10)	0.49	(0.28)	0.07	(0.08)	0.49	(0.47)	0.03	(0.10)	NA	NA
ele	0.59	(0.15)	0.94	(0.27)	0.45	(0.13)	1.03	(0.42)	0.54	(0.16)	NA	NA
fin	-0.04	(0.13)	0.32	(0.41)	-0.05	(0.10)	0.78	(0.71)	-0.04	(0.12)	NA	NA
foo	0.26	(0.11)	0.22	(0.20)	0.30	(0.09)	0.22	(0.53)	0.28	(0.12)	NA	NA
hea	-0.06	(0.11)	0.36	(0.48)	-0.05	(0.09)	0.44	(0.67)	-0.07	(0.11)	NA	NA
htl	-0.03	(0.10)	0.01	(0.13)	-0.04	(0.08)	-0.11	(0.16)	-0.02	(0.11)	NA	NA
lea	-0.02	(0.10)	0.30	(0.27)	-0.08	(0.09)	0.41	(0.65)	-0.09	(0.11)	NA	NA
ltr	-0.13	(0.12)	-0.05	(0.37)	-0.19	(0.11)	0.00	(0.77)	-0.13	(0.12)	NA	NA
mch	0.03	(0.10)	0.32	(0.24)	0.06	(0.08)	0.39	(0.42)	0.04	(0.11)	NA	NA
min	-0.36	(0.18)	0.23	(0.31)	-0.40	(0.16)	0.43	(0.41)	-0.50	(0.20)	NA	NA
mtl	0.11	(0.10)	0.28	(0.22)	0.07	(0.08)	0.07	(0.37)	0.13	(0.11)	NA	NA
mvh	0.41	(0.08)	0.65	(0.19)	0.38	(0.07)	0.43	(0.34)	0.40	(0.08)	NA	NA
nmm	0.04	(0.08)	0.48	(0.28)	-0.02	(0.07)	0.55	(0.55)	-0.01	(0.08)	NA	NA
oth	0.06	(0.12)	0.54	(0.34)	0.16	(0.10)	0.07	(0.48)	0.12	(0.12)	NA	NA
pet	0.03	(0.12)	0.48	(0.28)	-0.01	(0.09)	0.45	(0.40)	-0.03	(0.12)	NA	NA
ppp	0.01	(0.11)	0.31	(0.33)	-0.01	(0.09)	0.18	(0.72)	0.02	(0.11)	NA	NA
pub	-0.02	(0.11)	0.35	(0.93)	-0.05	(0.09)	0.87	(23.16)	-0.01	(0.10)	NA	NA
rea	0.20	(0.07)	-0.03	(0.22)	0.20	(0.06)	-0.08	(0.33)	0.21	(0.07)	NA	NA
ren	0.09	(0.08)	0.34	(0.19)	0.10	(0.07)	0.46	(0.39)	0.08	(0.08)	NA	NA
rub	0.26	(0.10)	0.63	(0.29)	0.25	(0.08)	0.63	(0.52)	0.25	(0.10)	NA	NA
srv	0.01	(0.08)	0.23	(0.21)	0.04	(0.07)	0.48	(0.33)	-0.04	(0.09)	NA	NA
teq	0.16	(0.10)	0.13	(0.19)	0.20	(0.08)	0.02	(0.36)	0.20	(0.10)	NA	NA
tex	-0.08	(0.10)	0.11	(0.23)	-0.12	(0.09)	0.12	(0.47)	-0.11	(0.11)	NA	NA
trd	0.21	(0.10)	0.75	(0.36)	0.22	(0.08)	1.02	(0.65)	0.17	(0.10)	NA	NA
trv	-0.19	(0.13)	-0.14	(0.41)	-0.25	(0.11)	-0.06	(0.90)	-0.19	(0.12)	NA	NA
whs	0.15	(0.10)	0.63	(0.38)	0.17	(0.08)	0.96	(0.68)	0.11	(0.10)	NA	NA
woo	0.02	(0.11)	0.39	(0.28)	-0.02	(0.08)	0.06	(0.48)	-0.02	(0.11)	NA	NA
wtr	-0.10	(0.12)	0.07	(0.44)	-0.14	(0.11)	0.24	(0.95)	-0.12	(0.11)	NA	NA

Source: Own elaboration

Summing up, it becomes apparent that obtained elasticity estimates differ to a quite large extent – not only between activity industries/products, but also between various nests of production function and between short- and long-run. In general, substitution elasticities between aggregate materials and capital-labour-energy composite (top nest), between value added and energy, as well as between capital and labour tend to be contained (with several exceptions) between zero (Leontief specification) and unity (Cobb-Douglas specification). It also turns out that substitution possibilities at the top level are generally greater than those between energy and value added, and (especially) between capital and labour. Substitution possibilities between labour skills seem to be questionable (very high variation coefficients), while the estimation outcomes differ significantly between the short- and long-term. Finally, Armington elasticities (i.e. those between domestic and imported materials) are mainly located around unity (again with numerous exceptions), i.e. technically close to Cobb-Douglas form.

As an extension, tables 13-18 provide results of test for Leontief or/and Cobb-Douglas specification, i.e. whether the estimated elasticity value in a given sector-nest combination is statistically different from zero or/and unity.

At the top nest, which combines aggregate materials and capital-labour-energy composite (see Table 13), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 3 out of 34 cases, while Cobb-Douglas specification should be be rejected in all of 34 cases. In the case of ECMs, short-term Leontief specification cannot be rejected in 4 out of 34 cases, while Cobb-Douglas specification cannot be rejected in 14 out of 34 cases. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 3 cases, while Cobb-Douglas should be rejected in all of 34 cases. However, this picture seems to change over the longer term, especially for the elasticity estimates derived from ECMs. In this case, Leontief function cannot be rejected in 14, while Cobb-Douglas function – in as much as 19 out of 34 cases. For ADLs, Leontief function cannot be rejected in 4, while Cobb-Douglas function – in 14 out of 34 cases. Notably, for the only sector with a negative elasticity estimate – *Transport equipment* (teq) in the long-term derived from ECM – the null hypothesis of zero elasticity cannot be rejected. This implies no substitution possibilities between aggregate materials and capital-labour-energy composite within this sector, i.e. the Leontief production function.

At the Armington nest, which combines domestic and imported materials (see Table 14), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 3 out of 34 cases, while Cobb-Douglas specification cannot be rejected in as much as 27 cases. In the case of ECMs, short-term Leontief specification cannot be rejected in 3 out of 34 cases, while Cobb-Douglas specification cannot be rejected in as much as 24 cases. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 3 out of 34 cases, while Cobb-Douglas cannot be rejected in as much as 28 cases. Over the longer term, for ECM-based estimates, Leontief function cannot be rejected in 16, while Cobb-Douglas function – in as much as 31 out of 34 cases. For ADLs, Leontief function cannot be rejected in 8, while Cobb-Douglas function – in as much as 29 out of 34 cases.

At the capital-labour-energy nest, which combines value added and energy (see Table 15), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 10 out of 34 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of ECMs, short-term Leontief specification cannot be rejected in 5 out of 34 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 17 cases, while Cobb-Douglas should be rejected in all of 34 cases. However, this picture seems to change over the longer term, especially for the elasticity estimates derived from ECMs. In this case, both Leontief and Cobb-Douglas function cannot be rejected in 20 out of 34 cases. For ADLs, Leontief function cannot be rejected in 16, while Cobb-Douglas function – in 10 out of 34 cases. Notably, for all 14 slightly negative estimates (both in short- and long-term, derived mainly from ECMs), the null hypothesis of zero elasticity cannot be rejected. This implies no substitution possibilities between value added and energy within these sectors, i.e. the Leontief production function.

At the value added nest, which combines capital and labour (see Table 16), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 9 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of ECMs, short-term Leontief specification also cannot be rejected in 8 cases, while Cobb-Douglas specification should be rejected in all of 34 case. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 10 cases, while Cobb-Douglas should be rejected in all of 34 cases. However, this picture changes to some extent over the longer term, especially for the elasticity estimates derived from ECMs. In this case, Leontief function cannot be rejected in as much as 22 cases, while Cobb-Douglas function – in 5 out of 34 cases. For ADLs, Leontief function cannot be rejected in 13 cases, while Cobb-Douglas function should be rejected in all of 34 cases. Notably, for 11 out of 12 slightly negative estimates (both in short- and long-term, derived mainly from ECMs), the null hypothesis of zero elasticity cannot be rejected. This implies no substitution possibilities between capital and labour within these sectors, i.e. the Leontief production function.

At the upper labour nest, which combines upper- and low-skilled labour (see Table 17), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 31 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of ECMs, short-term Leontief specification cannot be rejected in 30 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 29 cases, while Cobb-Douglas should be rejected in all of 34 cases. Hence, there seem to be practically no substitution possibilities within this nest in the short run. However, this picture seems to change dramatically over the longer run for elasticity estimates derived from ECMs. In this case, Leontief function cannot be rejected in 24 cases, while Cobb-Douglas function – cannot also be rejected in as much as in 27 out of 34 cases. For ADLs, Leontief function cannot be rejected in 24 cases, while Cobb-Douglas function cannot be rejected in 15 of 34 cases. Notably, in 6 out of 57 cases with negative point estimates, the null hypothesis of zero elasticity should be rejected. Hence, these elasticities cannot be described as "technically close to zero" and perceived as not significantly different from the Leontief specification.

At the lower labour nest, which combines high- and medium-skilled labour (see Table 18), Leontief specification for short-term elasticities derived from ADLs cannot be rejected in 26 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of ECMs, short-term Leontief specification cannot be rejected in 22 cases, while Cobb-Douglas specification should be rejected in all of 34 cases. In the case of equations for differenced variables, short-term Leontief specification cannot be rejected in 27 cases, while Cobb-Douglas should be rejected in all of 34 cases. Hence, there seem to be very limited substitution possibilities within this nest in the short run. However, this picture seems to change dramatically over the longer run, especially for elasticity estimates derived from ECMs. In this case, Leontief function cannot be rejected in 33 cases, while Cobb-Douglas function – in as much as 29 out of 34 cases. For ADLs, Leontief function cannot be rejected in 28 cases, while Cobb-Douglas function – in 13 out of 34 cases. Notably, in 5 out of 60 cases with negative point estimates, the null hypothesis of zero elasticity should be rejected. Hence, these elasticities cannot be described as "technically close to zero" and perceived as not significantly different from the Leontief specification.

In general, the results of Wald tests for Leontief/Cobb-Douglas specification of production functions do suggest that the quite common practice of using arbitrary, sector-uniform elasticity values (“coffee table elasticities”) in CGE models may not be justified.

Table 13. Wald test for Leontief and Cobb-Douglas specification of production function – top nest: σ(top)*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	6.88	0.00	-15.33	0.00	1.69	0.09	-7.25	0.00	8.98	0.00	-18.23	0.00	-1.01	0.31	3.94	0.00	7.45	0.00	-14.40	0.00	NA	NA	NA	NA
atr	11.55	0.00	-3.38	0.00	8.88	0.00	2.15	0.03	18.16	0.00	0.75	0.45	-8.96	0.00	-1.73	0.09	16.86	0.00	2.01	0.04	NA	NA	NA	NA
chm	5.81	0.00	-9.50	0.00	5.46	0.00	-6.97	0.00	7.17	0.00	-10.95	0.00	-3.00	0.00	4.47	0.00	4.35	0.00	-10.09	0.00	NA	NA	NA	NA
com	5.34	0.00	-5.17	0.00	3.34	0.00	-2.09	0.04	6.35	0.00	-5.90	0.00	-2.84	0.00	0.48	0.63	4.30	0.00	-4.11	0.00	NA	NA	NA	NA
con	7.73	0.00	-14.26	0.00	2.64	0.01	-5.11	0.00	8.57	0.00	-16.47	0.00	-1.35	0.18	3.91	0.00	7.20	0.00	-13.87	0.00	NA	NA	NA	NA
edu	5.02	0.00	-6.65	0.00	4.87	0.00	-0.94	0.35	6.41	0.00	-6.38	0.00	-4.19	0.00	0.71	0.48	4.58	0.00	-6.67	0.00	NA	NA	NA	NA
eeq	1.20	0.23	-7.87	0.00	2.92	0.00	-1.61	0.11	1.40	0.16	-8.58	0.00	-2.20	0.03	1.75	0.08	1.32	0.19	-7.51	0.00	NA	NA	NA	NA
ele	0.26	0.80	-12.00	0.00	0.94	0.35	-4.39	0.00	1.07	0.28	-13.68	0.00	0.00	1.00	3.84	0.00	0.10	0.92	-11.98	0.00	NA	NA	NA	NA
fin	3.78	0.00	-9.28	0.00	5.34	0.00	-1.90	0.06	4.45	0.00	-11.16	0.00	-4.03	0.00	1.00	0.32	2.69	0.01	-9.71	0.00	NA	NA	NA	NA
foo	6.98	0.00	-10.06	0.00	4.89	0.00	-8.12	0.00	7.63	0.00	-12.06	0.00	-3.58	0.00	6.02	0.00	5.94	0.00	-9.48	0.00	NA	NA	NA	NA
hea	4.12	0.00	-5.52	0.00	3.72	0.00	-1.21	0.23	5.22	0.00	-5.62	0.00	-1.73	0.08	0.40	0.69	3.55	0.00	-6.05	0.00	NA	NA	NA	NA
htl	8.08	0.00	-5.90	0.00	5.18	0.00	0.41	0.68	8.64	0.00	-7.79	0.00	-4.19	0.00	-1.12	0.26	6.51	0.00	-8.98	0.00	NA	NA	NA	NA
lea	5.48	0.00	-5.32	0.00	3.30	0.00	-1.05	0.29	6.27	0.00	-5.92	0.00	-1.87	0.06	1.36	0.17	5.08	0.00	-4.69	0.00	NA	NA	NA	NA
ltr	6.46	0.00	-10.64	0.00	2.06	0.04	-6.09	0.00	8.71	0.00	-12.76	0.00	-1.99	0.05	3.46	0.00	6.38	0.00	-10.77	0.00	NA	NA	NA	NA
mch	8.79	0.00	-5.45	0.00	5.27	0.00	0.25	0.80	10.89	0.00	-5.41	0.00	-2.50	0.01	-1.07	0.29	7.78	0.00	-6.64	0.00	NA	NA	NA	NA
min	4.65	0.00	-13.34	0.00	6.00	0.00	-1.49	0.14	4.80	0.00	-15.29	0.00	-3.32	0.00	0.36	0.72	3.14	0.00	-14.45	0.00	NA	NA	NA	NA
mtl	6.45	0.00	-11.61	0.00	3.80	0.00	-3.07	0.00	7.48	0.00	-12.81	0.00	-1.25	0.21	2.59	0.01	5.58	0.00	-11.79	0.00	NA	NA	NA	NA
mvh	7.85	0.00	-6.61	0.00	7.62	0.00	-0.66	0.51	9.13	0.00	-7.97	0.00	-5.45	0.00	-1.09	0.28	5.66	0.00	-8.40	0.00	NA	NA	NA	NA
nmm	4.89	0.00	-13.09	0.00	5.17	0.00	-3.24	0.00	4.97	0.00	-14.19	0.00	-2.66	0.01	1.59	0.11	3.50	0.00	-13.59	0.00	NA	NA	NA	NA
oth	19.46	0.00	-6.05	0.00	11.06	0.00	-1.02	0.31	22.82	0.00	-7.32	0.00	-6.15	0.00	-0.18	0.86	18.23	0.00	-6.67	0.00	NA	NA	NA	NA
pet	1.61	0.11	-10.97	0.00	2.01	0.05	-3.19	0.00	0.95	0.34	-12.92	0.00	-1.12	0.26	1.51	0.13	0.25	0.80	-12.09	0.00	NA	NA	NA	NA
ppp	7.60	0.00	-10.26	0.00	3.28	0.00	-6.93	0.00	8.44	0.00	-10.69	0.00	-4.21	0.00	4.34	0.00	7.15	0.00	-9.52	0.00	NA	NA	NA	NA
pub	3.68	0.00	-6.50	0.00	4.05	0.00	0.12	0.90	4.30	0.00	-7.82	0.00	-2.65	0.01	-0.11	0.91	2.64	0.01	-7.66	0.00	NA	NA	NA	NA
rea	4.00	0.00	-10.51	0.00	2.08	0.04	-0.25	0.80	4.39	0.00	-11.48	0.00	-1.45	0.15	-0.75	0.46	4.24	0.00	-10.56	0.00	NA	NA	NA	NA
ren	4.76	0.00	-3.99	0.00	2.90	0.00	-0.49	0.62	6.86	0.00	-5.34	0.00	-2.77	0.01	0.45	0.65	5.18	0.00	-4.73	0.00	NA	NA	NA	NA
rub	4.40	0.00	-11.85	0.00	3.50	0.00	-6.10	0.00	4.61	0.00	-13.22	0.00	-1.37	0.17	2.62	0.01	3.34	0.00	-12.28	0.00	NA	NA	NA	NA
srv	12.47	0.00	-6.03	0.00	9.54	0.00	-3.98	0.00	13.87	0.00	-6.84	0.00	-4.76	0.00	2.35	0.02	12.04	0.00	-5.96	0.00	NA	NA	NA	NA
teq	6.76	0.00	-6.59	0.00	0.48	0.63	-5.08	0.00	8.59	0.00	-6.63	0.00	0.41	0.68	4.47	0.00	7.80	0.00	-4.95	0.00	NA	NA	NA	NA
tex	2.74	0.01	-10.32	0.00	2.44	0.02	-7.27	0.00	3.18	0.00	-12.19	0.00	-1.48	0.14	3.62	0.00	2.81	0.01	-9.35	0.00	NA	NA	NA	NA
trd	9.66	0.00	-5.07	0.00	2.42	0.02	-3.43	0.00	10.98	0.00	-5.16	0.00	-1.07	0.28	1.23	0.22	10.29	0.00	-4.80	0.00	NA	NA	NA	NA
trv	7.26	0.00	-4.36	0.00	3.02	0.00	-1.45	0.15	8.00	0.00	-4.53	0.00	-2.11	0.04	-0.33	0.74	6.17	0.00	-4.38	0.00	NA	NA	NA	NA
whs	9.45	0.00	-6.61	0.00	4.37	0.00	-5.37	0.00	11.27	0.00	-7.23	0.00	-3.80	0.00	2.67	0.01	9.96	0.00	-6.24	0.00	NA	NA	NA	NA
woo	5.31	0.00	-11.56	0.00	3.25	0.00	-4.72	0.00	5.39	0.00	-12.98	0.00	-1.25	0.21	2.11	0.04	4.74	0.00	-12.18	0.00	NA	NA	NA	NA
wtr	7.35	0.00	-11.03	0.00	1.50	0.13	-6.07	0.00	8.92	0.00	-12.56	0.00	-0.95	0.34	4.39	0.00	8.58	0.00	-10.99	0.00	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief (σ=0) or Cobb-Douglas (σ=1) specification of production function

Source: Own elaboration

Table 14. Wald test for Leontief and Cobb-Douglas specification of production function – Armington nest: σ(armi)*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	8.39	0.00	-1.04	0.30	4.54	0.00	-2.09	0.04	9.74	0.00	-1.03	0.31	-3.43	0.00	0.88	0.38	9.15	0.00	-0.02	0.99	NA	NA	NA	NA
atr	2.11	0.04	-1.93	0.05	1.46	0.14	-1.72	0.09	2.31	0.02	-2.10	0.04	-0.53	0.60	1.83	0.07	2.86	0.00	-1.01	0.31	NA	NA	NA	NA
chm	6.99	0.00	0.66	0.51	4.60	0.00	0.61	0.54	8.22	0.00	0.68	0.50	-2.98	0.00	-0.83	0.41	6.64	0.00	0.27	0.79	NA	NA	NA	NA
com	9.57	0.00	0.01	0.99	7.28	0.00	-0.34	0.74	10.14	0.00	-0.83	0.41	-4.89	0.00	0.10	0.92	9.78	0.00	1.01	0.31	NA	NA	NA	NA
con	5.28	0.00	0.86	0.39	3.20	0.00	-1.21	0.23	6.48	0.00	0.75	0.45	-4.54	0.00	0.24	0.81	4.99	0.00	0.74	0.46	NA	NA	NA	NA
edu	2.37	0.02	-0.80	0.42	3.68	0.00	0.93	0.35	4.94	0.00	0.78	0.44	-2.98	0.00	-1.09	0.28	4.02	0.00	0.59	0.56	NA	NA	NA	NA
eeq	3.64	0.00	-0.59	0.56	0.89	0.37	-2.18	0.03	5.22	0.00	-0.29	0.77	-1.38	0.17	0.99	0.32	3.87	0.00	-0.14	0.89	NA	NA	NA	NA
ele	6.35	0.00	0.64	0.52	3.23	0.00	-0.28	0.78	6.61	0.00	-0.28	0.78	-1.81	0.07	0.49	0.62	6.87	0.00	0.95	0.34	NA	NA	NA	NA
fin	4.49	0.00	-2.33	0.02	2.39	0.02	-0.72	0.47	5.80	0.00	-2.28	0.02	-2.41	0.02	-0.30	0.77	4.45	0.00	-2.37	0.02	NA	NA	NA	NA
foo	9.70	0.00	-0.90	0.37	5.19	0.00	-2.68	0.01	12.16	0.00	-0.61	0.54	-4.55	0.00	1.33	0.18	10.05	0.00	-0.45	0.65	NA	NA	NA	NA
hea	3.83	0.00	-0.29	0.77	1.87	0.06	-0.58	0.56	4.45	0.00	0.02	0.98	-1.32	0.19	-0.07	0.94	4.79	0.00	0.74	0.46	NA	NA	NA	NA
htl	2.46	0.01	0.32	0.75	0.34	0.73	-1.07	0.28	3.41	0.00	0.77	0.44	-0.60	0.55	0.64	0.52	2.07	0.04	-0.09	0.93	NA	NA	NA	NA
lea	4.59	0.00	2.05	0.04	1.70	0.09	0.06	0.96	5.43	0.00	2.46	0.01	-0.96	0.34	0.02	0.98	4.58	0.00	2.12	0.03	NA	NA	NA	NA
ltr	2.31	0.02	-2.65	0.01	2.13	0.03	-0.11	0.91	2.50	0.01	-3.70	0.00	-0.84	0.40	0.61	0.54	2.03	0.04	-3.17	0.00	NA	NA	NA	NA
mch	3.83	0.00	-1.08	0.28	4.74	0.00	-0.09	0.93	4.89	0.00	-1.08	0.28	-3.05	0.00	0.49	0.63	4.73	0.00	0.23	0.82	NA	NA	NA	NA
min	2.97	0.00	-4.01	0.00	2.80	0.01	-2.73	0.01	3.09	0.00	-4.71	0.00	-1.76	0.08	1.97	0.05	2.72	0.01	-3.77	0.00	NA	NA	NA	NA
mtl	7.73	0.00	-1.43	0.15	7.60	0.00	2.65	0.01	9.40	0.00	-0.75	0.45	-5.48	0.00	-2.16	0.03	8.79	0.00	0.09	0.92	NA	NA	NA	NA
mvh	2.84	0.00	-2.02	0.04	1.89	0.06	-1.15	0.25	3.00	0.00	-2.35	0.02	-1.24	0.21	0.62	0.54	2.94	0.00	-1.68	0.09	NA	NA	NA	NA
nmm	10.74	0.00	0.77	0.44	3.81	0.00	-0.43	0.67	12.71	0.00	2.30	0.02	-3.67	0.00	0.27	0.79	11.26	0.00	1.91	0.06	NA	NA	NA	NA
oth	6.18	0.00	1.01	0.32	3.04	0.00	0.55	0.59	7.92	0.00	1.81	0.07	-1.02	0.31	0.36	0.72	7.10	0.00	1.74	0.08	NA	NA	NA	NA
pet	7.28	0.00	-0.63	0.53	6.38	0.00	1.57	0.12	9.30	0.00	-0.42	0.67	-5.00	0.00	-2.03	0.04	6.50	0.00	-0.90	0.37	NA	NA	NA	NA
ppp	11.97	0.00	1.75	0.08	2.79	0.01	-0.53	0.60	12.49	0.00	0.53	0.60	-3.20	0.00	0.12	0.91	10.61	0.00	0.46	0.64	NA	NA	NA	NA
pub	3.56	0.00	-0.31	0.76	5.73	0.00	1.15	0.25	4.46	0.00	-0.06	0.95	-2.76	0.01	-0.24	0.81	2.45	0.01	-1.09	0.28	NA	NA	NA	NA
rea	0.96	0.34	-1.44	0.15	3.04	0.00	1.40	0.16	1.04	0.30	-2.08	0.04	-1.86	0.06	-0.60	0.55	1.76	0.08	-0.83	0.41	NA	NA	NA	NA
ren	9.91	0.00	0.58	0.56	4.55	0.00	-1.28	0.20	12.61	0.00	0.83	0.41	-4.32	0.00	-0.33	0.74	10.45	0.00	0.45	0.66	NA	NA	NA	NA
rub	6.82	0.00	1.20	0.23	4.57	0.00	0.39	0.70	8.91	0.00	1.66	0.10	-3.87	0.00	-0.37	0.71	6.73	0.00	1.40	0.16	NA	NA	NA	NA
srv	7.06	0.00	0.60	0.55	5.13	0.00	1.13	0.26	7.65	0.00	0.14	0.89	-3.14	0.00	-0.80	0.43	5.90	0.00	-0.48	0.63	NA	NA	NA	NA
teq	3.80	0.00	-0.18	0.86	3.83	0.00	0.68	0.50	4.07	0.00	-0.30	0.77	-1.78	0.08	0.42	0.68	3.65	0.00	-0.01	0.99	NA	NA	NA	NA
tex	2.21	0.03	-1.72	0.09	2.03	0.04	-1.12	0.26	2.99	0.00	-1.76	0.08	-1.37	0.17	0.84	0.40	2.45	0.01	-1.19	0.24	NA	NA	NA	NA
trd	4.98	0.00	-1.10	0.27	4.25	0.00	-0.31	0.76	5.54	0.00	-1.72	0.09	-2.80	0.01	0.06	0.95	4.95	0.00	-0.78	0.44	NA	NA	NA	NA
trv	1.80	0.07	-2.13	0.03	1.80	0.07	-0.10	0.92	1.34	0.18	-3.91	0.00	-1.57	0.12	-0.07	0.94	1.77	0.08	-2.39	0.02	NA	NA	NA	NA
whs	3.17	0.00	-3.81	0.00	4.79	0.00	0.75	0.45	2.76	0.01	-4.91	0.00	-2.48	0.01	-0.41	0.68	2.41	0.02	-4.71	0.00	NA	NA	NA	NA
woo	9.69	0.00	-0.26	0.79	3.21	0.00	-0.94	0.35	10.18	0.00	-1.49	0.14	-1.51	0.13	0.47	0.64	8.84	0.00	-0.78	0.44	NA	NA	NA	NA
wtr	0.44	0.66	-1.21	0.23	1.73	0.09	1.12	0.26	1.18	0.24	-0.53	0.60	-0.29	0.77	-0.28	0.78	0.13	0.89	-1.60	0.11	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief (σ=0) or Cobb-Douglas (σ=1) specification of production function

Source: Own elaboration

Table 15. Wald test for Leontief and Cobb-Douglas specification of production function – capital-labour-energy nest: σ(kle)*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	4.41	0.00	-15.92	0.00	2.97	0.00	-2.29	0.02	5.03	0.00	-19.30	0.00	-2.79	0.01	0.81	0.42	3.89	0.00	-17.44	0.00	NA	NA	NA	NA
atr	2.30	0.02	-5.39	0.00	3.19	0.00	-0.42	0.67	2.84	0.01	-6.13	0.00	-2.32	0.02	-0.13	0.90	1.97	0.05	-5.36	0.00	NA	NA	NA	NA
chm	1.51	0.13	-16.90	0.00	1.21	0.23	-4.80	0.00	1.55	0.12	-19.52	0.00	-0.79	0.43	2.06	0.04	0.85	0.40	-17.77	0.00	NA	NA	NA	NA
com	2.20	0.03	-10.56	0.00	-0.19	0.85	-4.27	0.00	2.58	0.01	-13.07	0.00	0.25	0.80	3.05	0.00	3.02	0.00	-10.56	0.00	NA	NA	NA	NA
con	-0.82	0.41	-16.32	0.00	-1.04	0.30	-6.39	0.00	-0.57	0.57	-18.17	0.00	0.18	0.86	3.66	0.00	-0.53	0.60	-16.01	0.00	NA	NA	NA	NA
edu	1.17	0.24	-15.30	0.00	1.63	0.10	-3.72	0.00	1.27	0.20	-19.27	0.00	-2.21	0.03	1.75	0.08	0.12	0.91	-16.31	0.00	NA	NA	NA	NA
eeq	3.17	0.00	-9.81	0.00	4.27	0.00	-1.57	0.12	4.10	0.00	-11.59	0.00	-2.99	0.00	0.56	0.58	1.78	0.08	-11.36	0.00	NA	NA	NA	NA
ele	2.77	0.01	-17.57	0.00	-0.24	0.81	-11.03	0.00	4.19	0.00	-20.77	0.00	0.37	0.71	8.11	0.00	3.81	0.00	-16.04	0.00	NA	NA	NA	NA
fin	-0.03	0.97	-14.09	0.00	-0.06	0.96	-5.94	0.00	1.38	0.17	-15.58	0.00	-0.71	0.48	3.77	0.00	0.41	0.68	-12.79	0.00	NA	NA	NA	NA
foo	5.58	0.00	-14.34	0.00	4.81	0.00	-3.52	0.00	6.88	0.00	-18.02	0.00	-3.92	0.00	2.29	0.02	5.01	0.00	-15.00	0.00	NA	NA	NA	NA
hea	2.48	0.01	-17.35	0.00	3.48	0.00	-4.57	0.00	3.03	0.00	-20.60	0.00	-3.22	0.00	2.76	0.01	0.90	0.37	-18.23	0.00	NA	NA	NA	NA
htl	2.14	0.03	-15.60	0.00	3.13	0.00	-3.57	0.00	2.97	0.00	-17.49	0.00	-2.88	0.00	0.25	0.80	1.12	0.26	-16.65	0.00	NA	NA	NA	NA
lea	4.39	0.00	-5.06	0.00	4.59	0.00	0.68	0.49	4.53	0.00	-5.74	0.00	-2.08	0.04	-0.33	0.74	3.22	0.00	-6.26	0.00	NA	NA	NA	NA
ltr	4.62	0.00	-17.60	0.00	2.91	0.00	-1.85	0.07	4.98	0.00	-22.79	0.00	-1.34	0.18	1.91	0.06	3.89	0.00	-20.50	0.00	NA	NA	NA	NA
mch	5.04	0.00	-9.26	0.00	3.78	0.00	0.27	0.79	6.31	0.00	-11.66	0.00	-2.98	0.00	-1.12	0.26	3.85	0.00	-11.45	0.00	NA	NA	NA	NA
min	2.32	0.02	-9.85	0.00	-0.25	0.81	-5.57	0.00	3.00	0.00	-11.19	0.00	0.74	0.46	3.16	0.00	1.99	0.05	-9.85	0.00	NA	NA	NA	NA
mtl	2.35	0.02	-12.27	0.00	0.84	0.40	-4.45	0.00	2.68	0.01	-14.07	0.00	-0.65	0.52	2.92	0.00	2.05	0.04	-12.83	0.00	NA	NA	NA	NA
mvh	3.46	0.00	-8.25	0.00	1.93	0.06	-2.06	0.04	4.36	0.00	-8.79	0.00	-1.87	0.06	0.78	0.43	3.42	0.00	-7.95	0.00	NA	NA	NA	NA
nmm	2.03	0.04	-17.54	0.00	2.84	0.00	-3.06	0.00	3.19	0.00	-17.93	0.00	-2.37	0.02	0.19	0.85	1.08	0.28	-16.84	0.00	NA	NA	NA	NA
oth	3.12	0.00	-6.92	0.00	2.37	0.02	-0.53	0.60	3.32	0.00	-8.05	0.00	-1.46	0.15	0.00	1.00	2.57	0.01	-7.42	0.00	NA	NA	NA	NA
pet	9.04	0.00	-12.40	0.00	2.83	0.01	-4.19	0.00	12.55	0.00	-12.47	0.00	-1.82	0.07	1.11	0.27	10.73	0.00	-9.86	0.00	NA	NA	NA	NA
ppp	2.23	0.03	-15.32	0.00	2.74	0.01	-4.18	0.00	2.54	0.01	-14.05	0.00	-1.92	0.06	0.30	0.77	2.57	0.01	-13.07	0.00	NA	NA	NA	NA
pub	2.03	0.04	-19.86	0.00	0.81	0.42	-6.09	0.00	2.29	0.02	-21.92	0.00	-1.38	0.17	3.89	0.00	1.40	0.16	-18.89	0.00	NA	NA	NA	NA
rea	0.09	0.93	-15.09	0.00	-0.11	0.92	-6.08	0.00	0.68	0.50	-17.66	0.00	-0.47	0.64	3.64	0.00	0.62	0.54	-15.61	0.00	NA	NA	NA	NA
ren	2.53	0.01	-10.62	0.00	0.29	0.77	-4.00	0.00	3.38	0.00	-12.38	0.00	-0.68	0.50	1.57	0.12	2.70	0.01	-10.89	0.00	NA	NA	NA	NA
rub	1.94	0.05	-10.79	0.00	1.76	0.08	-1.78	0.08	2.57	0.01	-11.27	0.00	-1.52	0.13	0.51	0.61	1.64	0.10	-11.18	0.00	NA	NA	NA	NA
srv	2.14	0.03	-18.23	0.00	2.75	0.01	-4.74	0.00	2.45	0.01	-18.97	0.00	-2.32	0.02	2.99	0.00	1.58	0.11	-17.90	0.00	NA	NA	NA	NA
teq	3.23	0.00	-10.67	0.00	2.02	0.04	-3.59	0.00	4.93	0.00	-11.80	0.00	-1.63	0.10	2.77	0.01	3.25	0.00	-10.79	0.00	NA	NA	NA	NA
tex	3.23	0.00	-11.68	0.00	2.81	0.01	-1.71	0.09	3.88	0.00	-13.79	0.00	-2.28	0.02	0.18	0.86	3.28	0.00	-12.37	0.00	NA	NA	NA	NA
trd	1.88	0.06	-16.85	0.00	0.78	0.44	-4.48	0.00	3.46	0.00	-17.94	0.00	-1.29	0.20	1.64	0.10	1.84	0.07	-16.07	0.00	NA	NA	NA	NA
trv	5.69	0.00	-6.83	0.00	1.54	0.12	-2.43	0.02	6.68	0.00	-8.45	0.00	-1.29	0.20	0.81	0.42	5.78	0.00	-7.15	0.00	NA	NA	NA	NA
whs	1.85	0.07	-10.25	0.00	2.19	0.03	-1.43	0.15	2.25	0.02	-11.16	0.00	-2.18	0.03	-0.14	0.89	1.04	0.30	-10.43	0.00	NA	NA	NA	NA
woo	1.38	0.17	-12.12	0.00	0.36	0.72	-3.84	0.00	2.18	0.03	-14.25	0.00	-0.16	0.87	2.28	0.02	1.91	0.06	-12.14	0.00	NA	NA	NA	NA
wtr	1.50	0.14	-5.33	0.00	3.95	0.00	-0.88	0.38	2.47	0.01	-6.37	0.00	-3.10	0.00	0.29	0.78	0.87	0.38	-5.47	0.00	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief (σ=0) or Cobb-Douglas (σ=1) specification of production function

Source: Own elaboration

Table 16. Wald test for Leontief and Cobb-Douglas specification of production function – value added nest: σ(va)*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	1.18	0.24	-157.99	0.00	1.04	0.30	-16.65	0.00	2.09	0.04	-164.57	0.00	-0.96	0.34	11.50	0.00	1.36	0.17	-172.47	0.00	NA	NA	NA	NA
atr	5.82	0.00	-34.02	0.00	-0.25	0.80	-12.64	0.00	6.74	0.00	-41.53	0.00	1.02	0.31	13.39	0.00	6.92	0.00	-34.93	0.00	NA	NA	NA	NA
chm	6.81	0.00	-36.37	0.00	3.73	0.00	-5.10	0.00	7.86	0.00	-44.46	0.00	-2.63	0.01	2.42	0.02	6.44	0.00	-37.55	0.00	NA	NA	NA	NA
com	3.94	0.00	-73.00	0.00	5.12	0.00	-17.65	0.00	5.99	0.00	-70.13	0.00	-4.53	0.00	14.23	0.00	4.73	0.00	-57.41	0.00	NA	NA	NA	NA
con	4.27	0.00	-80.30	0.00	3.69	0.00	-21.77	0.00	3.00	0.00	-99.53	0.00	-0.14	0.89	13.55	0.00	2.68	0.01	-96.70	0.00	NA	NA	NA	NA
edu	1.77	0.08	-105.92	0.00	-0.76	0.45	-9.57	0.00	1.83	0.07	-105.77	0.00	0.44	0.66	5.00	0.00	2.67	0.01	-164.39	0.00	NA	NA	NA	NA
eeq	4.85	0.00	-84.08	0.00	2.46	0.01	-12.48	0.00	5.13	0.00	-88.74	0.00	-1.43	0.15	3.54	0.00	4.69	0.00	-90.79	0.00	NA	NA	NA	NA
ele	6.38	0.00	-32.29	0.00	2.98	0.00	-5.82	0.00	6.91	0.00	-37.64	0.00	-0.96	0.34	3.16	0.00	6.58	0.00	-38.90	0.00	NA	NA	NA	NA
fin	3.12	0.00	-69.15	0.00	2.29	0.02	-12.71	0.00	5.48	0.00	-62.67	0.00	-2.04	0.04	5.52	0.00	4.17	0.00	-67.47	0.00	NA	NA	NA	NA
foo	4.46	0.00	-54.39	0.00	3.79	0.00	-5.00	0.00	3.98	0.00	-58.57	0.00	-1.61	0.11	1.34	0.18	3.70	0.00	-59.01	0.00	NA	NA	NA	NA
hea	1.26	0.21	-133.79	0.00	0.54	0.59	-21.09	0.00	1.70	0.09	-131.97	0.00	0.05	0.96	17.41	0.00	1.98	0.05	-118.14	0.00	NA	NA	NA	NA
htl	1.37	0.17	-105.11	0.00	1.48	0.14	-26.05	0.00	1.24	0.22	-118.11	0.00	-1.35	0.18	20.54	0.00	1.22	0.22	-101.35	0.00	NA	NA	NA	NA
lea	-1.70	0.09	-78.91	0.00	0.85	0.40	-11.86	0.00	-1.17	0.24	-86.21	0.00	-1.38	0.17	2.24	0.03	-2.38	0.02	-89.81	0.00	NA	NA	NA	NA
ltr	1.93	0.05	-86.08	0.00	2.88	0.00	-12.67	0.00	1.97	0.05	-87.61	0.00	-2.07	0.04	6.76	0.00	0.58	0.56	-91.28	0.00	NA	NA	NA	NA
mch	6.05	0.00	-44.42	0.00	4.74	0.00	-3.90	0.00	7.08	0.00	-46.80	0.00	-3.04	0.00	1.90	0.06	4.37	0.00	-50.75	0.00	NA	NA	NA	NA
min	4.51	0.00	-91.74	0.00	2.10	0.04	-9.82	0.00	4.66	0.00	-94.45	0.00	-1.44	0.15	1.35	0.18	4.29	0.00	-106.70	0.00	NA	NA	NA	NA
mtl	6.82	0.00	-52.81	0.00	5.38	0.00	-17.22	0.00	8.18	0.00	-66.91	0.00	-3.68	0.00	14.90	0.00	5.97	0.00	-54.54	0.00	NA	NA	NA	NA
mvh	5.21	0.00	-51.71	0.00	3.75	0.00	-8.08	0.00	5.35	0.00	-53.13	0.00	-1.83	0.07	3.38	0.00	4.54	0.00	-56.80	0.00	NA	NA	NA	NA
nmm	6.91	0.00	-32.43	0.00	3.75	0.00	-5.58	0.00	7.45	0.00	-35.67	0.00	-4.12	0.00	5.18	0.00	5.31	0.00	-36.70	0.00	NA	NA	NA	NA
oth	2.76	0.01	-76.69	0.00	4.75	0.00	-16.61	0.00	3.08	0.00	-86.03	0.00	-3.69	0.00	11.96	0.00	1.56	0.12	-84.31	0.00	NA	NA	NA	NA
pet	3.23	0.00	-63.16	0.00	2.20	0.03	-4.03	0.00	3.02	0.00	-73.11	0.00	-0.55	0.58	0.84	0.40	2.46	0.01	-78.44	0.00	NA	NA	NA	NA
ppp	7.25	0.00	-45.76	0.00	2.16	0.03	-9.03	0.00	8.32	0.00	-50.16	0.00	-1.43	0.15	4.74	0.00	6.94	0.00	-47.62	0.00	NA	NA	NA	NA
pub	1.41	0.16	-123.09	0.00	0.76	0.45	-12.57	0.00	1.42	0.16	-122.72	0.00	-0.16	0.87	7.22	0.00	1.17	0.24	-130.45	0.00	NA	NA	NA	NA
rea	5.12	0.00	-15.91	0.00	-0.76	0.45	-6.31	0.00	5.71	0.00	-19.72	0.00	0.22	0.83	4.31	0.00	4.36	0.00	-17.95	0.00	NA	NA	NA	NA
ren	2.60	0.01	-67.42	0.00	4.18	0.00	-7.03	0.00	4.33	0.00	-58.24	0.00	-4.28	0.00	3.79	0.00	2.09	0.04	-62.23	0.00	NA	NA	NA	NA
rub	7.45	0.00	-25.38	0.00	3.90	0.00	-10.62	0.00	8.93	0.00	-28.91	0.00	-3.23	0.00	4.78	0.00	9.00	0.00	-24.65	0.00	NA	NA	NA	NA
srv	-0.32	0.75	-78.16	0.00	-0.32	0.75	-13.49	0.00	1.54	0.12	-118.89	0.00	-0.03	0.97	8.24	0.00	0.71	0.48	-134.00	0.00	NA	NA	NA	NA
teq	3.14	0.00	-72.19	0.00	1.36	0.17	-20.54	0.00	4.01	0.00	-77.99	0.00	-1.70	0.09	12.18	0.00	3.43	0.00	-64.91	0.00	NA	NA	NA	NA
tex	2.09	0.04	-92.61	0.00	1.97	0.05	-21.89	0.00	2.39	0.02	-103.85	0.00	-2.56	0.01	11.24	0.00	1.49	0.14	-101.21	0.00	NA	NA	NA	NA
trd	1.19	0.24	-146.07	0.00	0.37	0.71	-17.08	0.00	1.73	0.08	-169.66	0.00	-0.36	0.72	11.56	0.00	1.69	0.09	-165.82	0.00	NA	NA	NA	NA
trv	2.43	0.02	-111.04	0.00	3.19	0.00	-14.32	0.00	2.76	0.01	-127.68	0.00	-2.38	0.02	6.57	0.00	0.58	0.57	-129.92	0.00	NA	NA	NA	NA
whs	2.31	0.02	-43.48	0.00	3.03	0.00	-10.05	0.00	1.05	0.29	-49.39	0.00	-0.62	0.54	5.82	0.00	0.97	0.33	-54.35	0.00	NA	NA	NA	NA
woo	7.00	0.00	-73.63	0.00	2.52	0.01	-16.43	0.00	8.72	0.00	-81.39	0.00	-1.77	0.08	7.65	0.00	7.18	0.00	-78.02	0.00	NA	NA	NA	NA
wtr	3.43	0.00	-41.74	0.00	1.13	0.26	-5.40	0.00	4.04	0.00	-47.34	0.00	-0.69	0.49	0.15	0.88	3.46	0.00	-50.79	0.00	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief (σ=0) or Cobb-Douglas (σ=1) specification of production function

Source: Own elaboration

Table 17. Wald test for Leontief and Cobb-Douglas specification of production function – upper labour nest: σ(labu)*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)		σ=0 (Leontief)		σ=1 (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	0.18	0.86	-11.82	0.00	1.56	0.12	-1.35	0.18	0.08	0.94	-15.43	0.00	-1.67	0.10	0.38	0.70	-0.83	0.41	-14.34	0.00	NA	NA	NA	NA
atr	-0.52	0.60	-22.63	0.00	0.72	0.48	-6.94	0.00	-0.73	0.46	-27.70	0.00	-0.48	0.63	4.91	0.00	-0.79	0.43	-21.76	0.00	NA	NA	NA	NA
chm	1.35	0.18	-13.47	0.00	1.35	0.18	-3.04	0.00	1.63	0.10	-15.66	0.00	-1.31	0.19	1.70	0.09	0.85	0.40	-16.30	0.00	NA	NA	NA	NA
com	2.84	0.00	-7.44	0.00	1.58	0.12	-2.34	0.02	3.66	0.00	-9.58	0.00	-1.51	0.13	1.45	0.15	2.44	0.02	-8.31	0.00	NA	NA	NA	NA
con	0.21	0.84	-14.57	0.00	1.25	0.21	-1.31	0.19	-0.11	0.91	-17.87	0.00	-1.08	0.28	0.42	0.68	-0.63	0.53	-18.41	0.00	NA	NA	NA	NA
edu	1.91	0.06	-10.76	0.00	1.81	0.07	-0.76	0.45	2.33	0.02	-12.64	0.00	-1.55	0.12	0.17	0.86	1.53	0.13	-12.31	0.00	NA	NA	NA	NA
eeq	1.90	0.06	-15.16	0.00	1.51	0.13	-2.63	0.01	1.91	0.06	-18.37	0.00	-1.01	0.31	2.37	0.02	1.49	0.14	-18.06	0.00	NA	NA	NA	NA
ele	0.69	0.49	-7.54	0.00	2.98	0.00	0.11	0.92	0.72	0.47	-9.41	0.00	-2.94	0.00	-0.52	0.61	-1.09	0.28	-10.28	0.00	NA	NA	NA	NA
fin	2.38	0.02	-8.05	0.00	0.66	0.51	-2.99	0.00	2.60	0.01	-9.66	0.00	-0.43	0.67	1.77	0.08	2.63	0.01	-8.30	0.00	NA	NA	NA	NA
foo	0.97	0.33	-22.18	0.00	2.75	0.01	-0.31	0.76	0.79	0.43	-27.29	0.00	-2.41	0.02	-0.78	0.44	-1.14	0.26	-29.27	0.00	NA	NA	NA	NA
hea	-0.26	0.79	-13.99	0.00	1.40	0.16	-1.70	0.09	-0.15	0.88	-15.75	0.00	-1.71	0.09	-0.48	0.63	-1.18	0.24	-16.52	0.00	NA	NA	NA	NA
htl	-2.35	0.02	-17.01	0.00	0.84	0.40	-0.66	0.51	-3.16	0.00	-21.36	0.00	-0.52	0.60	0.43	0.67	-3.62	0.00	-21.13	0.00	NA	NA	NA	NA
lea	0.26	0.79	-21.95	0.00	2.52	0.01	-0.63	0.53	-0.06	0.95	-27.49	0.00	-2.49	0.01	-0.36	0.72	-1.90	0.06	-29.19	0.00	NA	NA	NA	NA
ltr	-0.37	0.71	-15.33	0.00	0.72	0.47	-2.55	0.01	-0.20	0.84	-18.55	0.00	-0.77	0.44	0.95	0.34	-0.99	0.32	-18.51	0.00	NA	NA	NA	NA
mch	-1.17	0.24	-19.44	0.00	1.54	0.12	-3.15	0.00	-1.45	0.15	-23.25	0.00	-1.88	0.06	-0.17	0.86	-2.64	0.01	-23.56	0.00	NA	NA	NA	NA
min	0.14	0.89	-8.69	0.00	0.41	0.68	-3.25	0.00	0.25	0.80	-10.06	0.00	-0.43	0.67	2.61	0.01	-0.38	0.70	-9.72	0.00	NA	NA	NA	NA
mtl	-0.23	0.81	-24.65	0.00	2.04	0.04	-1.38	0.17	-0.43	0.67	-29.68	0.00	-2.12	0.03	-0.08	0.93	-2.13	0.03	-32.35	0.00	NA	NA	NA	NA
mvh	0.42	0.67	-18.02	0.00	0.95	0.34	-1.88	0.06	0.13	0.90	-21.33	0.00	-1.02	0.31	0.17	0.87	-0.30	0.76	-22.99	0.00	NA	NA	NA	NA
nmm	0.96	0.34	-19.81	0.00	1.84	0.07	-2.32	0.02	1.14	0.25	-23.93	0.00	-1.88	0.06	0.50	0.62	-0.16	0.88	-25.14	0.00	NA	NA	NA	NA
oth	1.95	0.05	-19.15	0.00	3.16	0.00	-0.94	0.35	1.89	0.06	-20.64	0.00	-2.59	0.01	-0.62	0.53	-0.07	0.94	-22.92	0.00	NA	NA	NA	NA
pet	-1.64	0.10	-9.26	0.00	0.96	0.34	-3.90	0.00	-1.72	0.09	-10.27	0.00	-1.04	0.30	3.06	0.00	-1.87	0.06	-9.62	0.00	NA	NA	NA	NA
ppp	0.44	0.66	-18.00	0.00	1.43	0.15	-2.42	0.02	0.92	0.36	-21.25	0.00	-2.11	0.04	0.41	0.68	-0.43	0.67	-22.91	0.00	NA	NA	NA	NA
pub	0.37	0.71	-9.85	0.00	-0.90	0.37	-3.63	0.00	0.51	0.61	-11.67	0.00	0.67	0.50	2.11	0.04	1.19	0.24	-10.61	0.00	NA	NA	NA	NA
rea	1.63	0.10	-13.83	0.00	2.84	0.00	-1.97	0.05	1.80	0.07	-17.34	0.00	-2.66	0.01	1.02	0.31	0.58	0.56	-16.92	0.00	NA	NA	NA	NA
ren	0.59	0.55	-16.86	0.00	0.90	0.37	-2.79	0.01	0.30	0.76	-21.15	0.00	-0.27	0.79	2.01	0.04	0.33	0.74	-20.22	0.00	NA	NA	NA	NA
rub	0.53	0.60	-20.49	0.00	2.06	0.04	-2.30	0.02	0.53	0.60	-24.67	0.00	-1.98	0.05	0.36	0.72	-1.02	0.31	-26.50	0.00	NA	NA	NA	NA
srv	-0.68	0.50	-13.91	0.00	-1.72	0.09	-5.14	0.00	-0.71	0.48	-16.38	0.00	1.50	0.13	3.51	0.00	0.31	0.76	-14.07	0.00	NA	NA	NA	NA
teq	1.87	0.06	-20.21	0.00	3.05	0.00	-1.48	0.14	1.76	0.08	-26.16	0.00	-2.71	0.01	-0.14	0.89	0.32	0.75	-23.55	0.00	NA	NA	NA	NA
tex	0.31	0.76	-21.73	0.00	2.35	0.02	-0.84	0.40	-0.06	0.95	-27.01	0.00	-2.26	0.02	-0.08	0.94	-1.67	0.10	-28.88	0.00	NA	NA	NA	NA
trd	-0.26	0.79	-19.88	0.00	1.04	0.30	-1.48	0.14	-0.54	0.59	-24.34	0.00	-1.05	0.29	0.02	0.99	-1.30	0.19	-25.70	0.00	NA	NA	NA	NA
trv	-0.53	0.60	-12.46	0.00	0.24	0.81	-2.71	0.01	-0.44	0.66	-15.16	0.00	-0.11	0.91	1.45	0.15	-0.90	0.37	-14.91	0.00	NA	NA	NA	NA
whs	-0.14	0.89	-18.54	0.00	0.68	0.50	-2.07	0.04	-0.24	0.81	-22.96	0.00	-0.80	0.42	0.44	0.66	-0.82	0.41	-23.61	0.00	NA	NA	NA	NA
woo	-0.01	1.00	-23.50	0.00	2.39	0.02	-1.25	0.21	-0.24	0.81	-29.21	0.00	-1.86	0.06	0.90	0.37	-1.51	0.13	-29.82	0.00	NA	NA	NA	NA
wtr	-0.83	0.41	-14.82	0.00	0.35	0.73	-2.85	0.00	-1.13	0.26	-18.52	0.00	-0.35	0.73	1.88	0.06	-1.55	0.12	-18.61	0.00	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief (σ=0) or Cobb-Douglas (σ=1) specification of production function

Source: Own elaboration

Table 18. Wald test for Leontief and Cobb-Douglas specification of production function – lower labour nest: $\sigma(labl)$*

	ADL								ECM								difference equation							
	short-run				long-run				short-run				long-run				short-run				long-run			
	$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)		$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)		$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)		$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)		$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)		$\sigma=0$ (Leontief)		$\sigma=1$ (Cobb-Douglas)	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
agr	-1.09	0.28	-9.08	0.00	0.39	0.70	-2.10	0.04	-1.38	0.17	-10.79	0.00	-0.41	0.68	0.80	0.43	-1.51	0.13	-9.69	0.00	NA	NA	NA	NA
atr	-0.60	0.55	-8.67	0.00	-0.07	0.95	-2.48	0.01	-1.02	0.31	-10.20	0.00	-0.17	0.86	0.92	0.36	-0.58	0.56	-9.06	0.00	NA	NA	NA	NA
chm	0.74	0.46	-8.36	0.00	2.23	0.03	-1.55	0.12	0.58	0.56	-10.34	0.00	-1.25	0.21	0.87	0.38	0.17	0.86	-8.53	0.00	NA	NA	NA	NA
com	-1.24	0.21	-8.45	0.00	0.04	0.97	-2.08	0.04	-0.72	0.47	-9.80	0.00	-0.18	0.86	1.13	0.26	-0.64	0.52	-8.14	0.00	NA	NA	NA	NA
con	-2.34	0.02	-8.70	0.00	-2.40	0.02	-4.32	0.00	-2.77	0.01	-10.72	0.00	1.87	0.06	3.17	0.00	-1.76	0.08	-8.20	0.00	NA	NA	NA	NA
edu	2.49	0.01	-8.58	0.00	1.02	0.31	-2.58	0.01	3.21	0.00	-10.45	0.00	-0.82	0.41	1.67	0.10	2.44	0.02	-8.59	0.00	NA	NA	NA	NA
eeq	0.67	0.51	-9.07	0.00	1.74	0.08	-1.80	0.07	0.81	0.42	-11.07	0.00	-1.02	0.31	1.08	0.28	0.32	0.75	-9.24	0.00	NA	NA	NA	NA
ele	3.88	0.00	-2.72	0.01	3.41	0.00	-0.24	0.81	3.38	0.00	-4.09	0.00	-2.46	0.01	-0.07	0.95	3.40	0.00	-2.91	0.00	NA	NA	NA	NA
fin	-0.31	0.76	-8.21	0.00	0.78	0.44	-1.65	0.10	-0.52	0.60	-10.94	0.00	-1.11	0.27	0.31	0.76	-0.35	0.72	-8.50	0.00	NA	NA	NA	NA
foo	2.39	0.02	-6.79	0.00	1.10	0.27	-3.82	0.00	3.19	0.00	-7.43	0.00	-0.42	0.68	1.46	0.14	2.34	0.02	-6.12	0.00	NA	NA	NA	NA
hea	-0.52	0.60	-9.80	0.00	0.76	0.45	-1.34	0.18	-0.64	0.53	-12.23	0.00	-0.65	0.52	0.84	0.40	-0.68	0.50	-10.01	0.00	NA	NA	NA	NA
htl	-0.26	0.79	-10.78	0.00	0.07	0.94	-7.35	0.00	-0.47	0.64	-13.72	0.00	0.69	0.49	6.91	0.00	-0.22	0.82	-9.68	0.00	NA	NA	NA	NA
lea	-0.21	0.84	-9.80	0.00	1.11	0.27	-2.54	0.01	-0.86	0.39	-11.80	0.00	-0.64	0.53	0.90	0.37	-0.82	0.42	-10.09	0.00	NA	NA	NA	NA
ltr	-1.06	0.29	-9.29	0.00	-0.13	0.90	-2.80	0.01	-1.76	0.08	-11.24	0.00	0.01	1.00	1.31	0.19	-1.07	0.29	-9.43	0.00	NA	NA	NA	NA
mch	0.27	0.79	-9.46	0.00	1.31	0.19	-2.78	0.01	0.67	0.50	-11.39	0.00	-0.91	0.36	1.45	0.15	0.39	0.70	-9.08	0.00	NA	NA	NA	NA
min	-1.92	0.06	-7.33	0.00	0.73	0.46	-2.47	0.01	-2.55	0.01	-8.89	0.00	-1.03	0.31	1.39	0.17	-2.50	0.01	-7.50	0.00	NA	NA	NA	NA
mtl	1.07	0.28	-8.45	0.00	1.31	0.19	-3.32	0.00	0.86	0.39	-10.91	0.00	-0.20	0.84	2.49	0.01	1.16	0.25	-7.87	0.00	NA	NA	NA	NA
mvh	4.93	0.00	-7.17	0.00	3.31	0.00	-1.82	0.07	5.57	0.00	-8.96	0.00	-1.29	0.20	1.67	0.10	4.90	0.00	-7.43	0.00	NA	NA	NA	NA
nmm	0.48	0.63	-11.44	0.00	1.74	0.08	-1.85	0.07	-0.30	0.76	-14.54	0.00	-1.00	0.32	0.81	0.42	-0.16	0.88	-12.43	0.00	NA	NA	NA	NA
oth	0.46	0.64	-7.74	0.00	1.59	0.11	-1.33	0.19	1.59	0.11	-8.45	0.00	-0.15	0.88	1.92	0.06	1.01	0.31	-7.13	0.00	NA	NA	NA	NA
pet	0.23	0.82	-8.28	0.00	1.69	0.09	-1.85	0.07	-0.16	0.87	-10.76	0.00	-1.14	0.26	1.38	0.17	-0.27	0.79	-8.61	0.00	NA	NA	NA	NA
ppp	0.11	0.91	-9.02	0.00	0.94	0.35	-2.07	0.04	-0.09	0.93	-11.24	0.00	-0.24	0.81	1.14	0.26	0.22	0.82	-8.81	0.00	NA	NA	NA	NA
pub	-0.22	0.83	-9.51	0.00	0.37	0.71	-0.71	0.48	-0.61	0.54	-11.81	0.00	-0.04	0.97	0.01	1.00	-0.11	0.91	-9.75	0.00	NA	NA	NA	NA
rea	2.66	0.01	-10.72	0.00	-0.13	0.89	-4.65	0.00	3.29	0.00	-13.08	0.00	0.24	0.81	3.24	0.00	2.83	0.00	-10.82	0.00	NA	NA	NA	NA
ren	1.21	0.23	-11.64	0.00	1.77	0.08	-3.46	0.00	1.43	0.16	-13.24	0.00	-1.17	0.24	1.38	0.17	0.97	0.33	-11.36	0.00	NA	NA	NA	NA
rub	2.59	0.01	-7.24	0.00	2.18	0.03	-1.29	0.20	2.98	0.00	-9.16	0.00	-1.23	0.22	0.71	0.48	2.38	0.02	-7.25	0.00	NA	NA	NA	NA
srv	0.06	0.95	-11.85	0.00	1.09	0.28	-3.73	0.00	0.56	0.58	-12.96	0.00	-1.45	0.15	1.55	0.12	-0.42	0.68	-12.08	0.00	NA	NA	NA	NA
teq	1.56	0.12	-8.43	0.00	0.66	0.51	-4.58	0.00	2.33	0.02	-9.45	0.00	-0.06	0.96	2.74	0.01	1.93	0.05	-7.62	0.00	NA	NA	NA	NA
tex	-0.75	0.46	-10.55	0.00	0.51	0.61	-3.93	0.00	-1.34	0.18	-12.79	0.00	-0.26	0.80	1.86	0.06	-1.00	0.32	-10.31	0.00	NA	NA	NA	NA
trd	2.13	0.03	-7.80	0.00	2.09	0.04	-0.68	0.49	2.77	0.01	-9.76	0.00	-1.57	0.12	-0.02	0.98	1.74	0.08	-8.28	0.00	NA	NA	NA	NA
trv	-1.50	0.13	-9.32	0.00	-0.33	0.74	-2.75	0.01	-2.21	0.03	-11.12	0.00	0.06	0.95	1.17	0.24	-1.55	0.12	-9.69	0.00	NA	NA	NA	NA
whs	1.46	0.14	-8.30	0.00	1.67	0.10	-0.97	0.33	2.07	0.04	-10.29	0.00	-1.41	0.16	0.06	0.95	1.13	0.26	-8.78	0.00	NA	NA	NA	NA
woo	0.15	0.88	-9.34	0.00	1.39	0.16	-2.18	0.03	-0.28	0.78	-12.07	0.00	-0.12	0.91	1.97	0.05	-0.16	0.87	-9.53	0.00	NA	NA	NA	NA
wtr	-0.80	0.42	-9.13	0.00	0.17	0.87	-2.09	0.04	-1.33	0.19	-10.81	0.00	-0.25	0.80	0.81	0.42	-1.07	0.28	-9.96	0.00	NA	NA	NA	NA

**p-value lower than 0.05 suggests rejecting the null hypothesis* of either Leontief ($\sigma=0$) or Cobb-Douglas ($\sigma=1$) specification of production function

Source: Own elaboration

7. Conclusions

The aim of this paper has been to provide a wide range of estimates of substitution elasticities for sectoral nested CES production functions, using panel data techniques, with the World Input-Output Database (WIOD) as the main data source. Such a large-scale estimation of various sectoral elasticities with a use of a common database and common methodology constituted an attempt to close this identified literature gap. The economic relations to be estimated have been derived from firm's profit maximization problem as first order conditions (FOCs) representing ratios of factor inputs as functions of their price ratios. In addition, time series properties of panel data (stationarity and cointegration) have also been carefully assessed, so that appropriate model specifications are used in particular sectors and production function nests. The inclusion of time adjustments in estimated equations has also allowed to distinguish between short- and long-run elasticity values.

A significant heterogeneity in estimated elasticity values has been observed between various activity sectors, as well as between various nests of the production function. It also turns out that, in vast majority of the sector-nest combinations, obtained long-run elasticities are higher than in the short run. Obtained elasticity estimates differ to a quite large extent – not only between activity sectors, but also between various nests of production function and between short- and long-run. In general, substitution elasticities between aggregate materials and capital-labour-energy composite (top nest), between value added and energy, as well as between capital and labour tend to be contained (with several exceptions) between zero (Leontief specification) and unity (Cobb-Douglas specification). It also turns out that substitution possibilities at the top level are generally greater than those between energy and value added, and (especially) between capital and labour. Substitution possibilities between labour skills seem to be questionable, although the estimation outcomes differ significantly between model specifications, as well as between the short- and long-term. Finally, Armington elasticities (i.e. those between domestic and imported materials) are mainly located around unity (again with some exceptions), i.e. technically close to Cobb-Douglas form. The results of Wald tests for Leontief/Cobb-Douglas specification of production functions do suggest that the quite common practice of using arbitrary, sector-uniform elasticity values ("coffee table elasticities") in CGE models may not be justified.

In addition, the analytical specification of estimated equation and time series properties of panel data (stationarity and cointegration) play a crucial role in determining the type of dynamic model (autoregressive distributed lag model, error correction model or model for differenced series) to be estimated for a particular sector-nest combination and, in turn, in determining the obtained values of elasticity estimates.

The elasticity estimates reported in this study may be subsequently used by CGE modellers in their applied research.

References

1. Armington P. (1969), “A Theory of Demand for Products Distinguished by Place of Production”, International Monetary Fund Staff Papers, Vol. 16, No. 1, pp. 170–201.
2. Arrow K., Chenery B., Minhas B., Solow R. (1961), “Capital-labor substitution and economic efficiency", The Review of Economics and Statistics, Vol. 43, No. 3, pp. 225-250.
3. Baccianti C. (2013), “Estimation of Sectoral Elasticities of Substitution Along the International Technology Frontier”, ZEW Discussion Paper No. 13-092, Centre for European Economic Research (ZEW).
4. Balistreri E., McDaniel C., Wong E. (2003), “An estimation of US industry-level capital-labor substitution elasticities: support for Cobb-Douglas”, North American Journal of Economics and Finance Vol. 14, No. 3, pp. 343-356.
5. Broadstock D., Hunt L., Sorrell S. (2007), “UKERC Review of Evidence for the Rebound Effect. Technical Report 3: Elasticity of substitution studies”, Working Paper – REF UKERC/WP/TPA/2007/011, UK Energy Research Centre.
6. Chambers R. (1988), “Applied Production Analysis: A Dual Approach”, Cambridge University Press, Cambridge.
7. Claro S. (2003), “A cross-country estimation of the elasticity of substitution between labor and capital in manufacturing industries”, Cuadernos de Economia, Vol. 40, No. 120, pp. 239-257.
8. Coelli T, Rao D., O'Donnell C., Battese G. (2005), “An introduction to efficiency and productivity analysis (Second edition)”, Springer.
9. Dawkins C., Srinivasan T., Whalley J., Heckman J. (2001), “Calibration” [in:] “Handbook of Econometrics”, Vol. 5, Chapter 58, pp. 3653-3703.
10. Fragiadakis K., Paroussos L., Kouvaritakis N., Capros P. (2012), “A Multi-Country Econometric Estimation of the Constant Elasticity of Substitution”, E3M-Lab, Institute of Communication and Computer Systems, National Technical University of Athens, Paper prepared for the WIOD project.
11. Henningsen A., Henningsen G. (2011), “Econometric Estimation of the Constant Elasticity of Substitution Function in R: Package micEconCES”, FOI Working Paper No. 2011/9, Institute of Food and Resource Economies, University of Copenhagen.
12. Hicks J. (1932), “The Theory of Wages”, Macmillan, London.
13. Jalava J., Pohjola M., Ripatti A., Vilmunen J. (2006), “Biased technical change and capital-labour substitution in Finland, 1902–2003”, Topics in Macroeconomics, Vol. 6, No. 1, pp. 1-20.
14. Kemfert C. (1998), “Estimated substitution elasticities of a nested CES production function approach for Germany”, Energy Economics, Vol. 20, No. 3, pp. 249-264.
15. Koesler S., Schymura M. (2012), “Substitution Elasticities in a CES Production Framework. An Empirical Analysis on the Basis of Non-Linear Least Squares Estimations”, ZEW Discussion Paper No. 12-007, Centre for European Economic Research (ZEW).
16. Maddala G., Kadane J. (1967), “Estimation of Returns to Scale and the Elasticity of Substitution”, Econometrica, Vol. 35, No. 3/4, pp. 419-423.
17. Mas-Colell A., Whinston M., Green J. (1995), “Microeconomic Theory”, Oxford University Press, New York.
18. Németh G., Szabó L., Ciscar J. (2011), “Estimation of Armington elasticities in a CGE economy-energy-environment model for Europe”, Economic Modelling, Vol. 28, No. 4, pp. 1993–1999.

19. Okagawa A., Ban K. (2008), "Estimation of substitution elasticities for CGE models", Discussion Papers in Economics and Business No. 08-16, Osaka University.
20. Prywes, M. (1986), "A nested CES approach to capital-energy substitution", Energy Economics, Vol. 8, No. 1, pp. 22-28.
21. Sato K (1967), "A Two-Level Constant-Elasticity-of-Substitution Production Function", The Review of Economic Studies, Vol. 34, No. 2, pp. 201-218.
22. Saito M. (2004), "Armington Elasticities in Intermediate Inputs Trade: A Problem in Using Multilateral Trade Data", IMF Working Paper No. WP/04/22, International Monetary Fund.
23. Thursby J., Lovell C. (1978), "An Investigation of the Kmenta Approximation to the CES Function", International Economic Review Vol. 19, No. 2, pp. 363-377.
24. Timmer M., Dietzenbacher E., Los B., Stehrer R., de Vries G. (2015), "An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production", Review of International Economics., Vol. 23, No. 3, pp. 575–605.
25. Tipper A. (2012), "Capital-labour substitution elasticities in New Zealand: one for all industries?", Statistics New Zealand Working Paper No. 12–01.
26. Turner K., Lange I., Lecca P., Jung Ha S. (2012), "Econometric estimation of nested production functions and testing in a computable general equilibrium analysis of economy-wide rebound effects", Stirling Economics Discussion Paper 2012-08, Stirling Management School, University of Stirling.
27. van der Werf E. (2008), "Production functions for climate policy modeling: An empirical analysis", Energy Economics, Vol. 30, No. 6, pp. 2964-2979.
28. Zachłod-Jelec M., Boratyński J. (2016), "How large and uncertain are costs of 2030 GHG emissions reduction target for the European countries? Sensitivity analysis in a global CGE model", MF Working Paper No. 24-2016, Ministry of Finance, Republic of Poland.

Annex

Table 19. Concordance between regions in WIOD and OECD Energy Prices and Taxes

WIOD		OECD
AUS	Australia	Australia
AUT	Austria	Austria
BEL	Belgium	Belgium
BRA	Brazil	
BGR	Bulgaria	
CAN	Canada	Canada
		Chile
CHN	China	
CYP	Cyprus	
CZE	Czech Republic	Czech Republic
DNK	Denmark	Denmark
EST	Estonia	Estonia
FIN	Finland	Finland
FRA	France	France
DEU	Germany	Germany
GRC	Greece	Greece
HUN	Hungary	Hungary
IND	India	
IDN	Indonesia	
IRL	Ireland	Ireland
		Israel
ITA	Italy	Italy
JPN	Japan	Japan
KOR	Korea, Republic of	Korea
LVA	Latvia	Latvia
LTU	Lithuania	
LUX	Luxembourg	Luxembourg
MLT	Malta	
MEX	Mexico	Mexico
NLD	Netherlands	Netherlands
		New Zealand
		Norway
POL	Poland	Poland
PRT	Portugal	Portugal
ROU	Romania	
RUS	Russia	
SVK	Slovak Republic	Slovak Republic
SVN	Slovenia	Slovenia
ESP	Spain	Spain
SWE	Sweden	Sweden
		Switzerland
TWN	Taiwan	
TUR	Turkey	Turkey
GBR	United Kingdom	United Kingdom
USA	United States	United States

Note: grey font indicates regions excluded from further analysis.

Table 20. Concordance between energy carriers in WIOD and OECD Energy Prices and Taxes

WIOD		OECD
HCOAL	Hard coal and derivatives	Steam coal
BCOAL	Lignite and derivatives	Steam coal
COKE	Coke	Coking coal
CRUDE	Crude oil, NGL and feedstocks	
DIESEL	Diesel oil for road transport	Automotive diesel
GASOLINE	Motor gasoline	Premium leaded gasoline Premium unleaded 95 RON Premium unleaded 98 RON Regular unleaded gasoline Regular leaded gasoline
JETFUEL	Jet fuel (kerosene and gasoline)	
LFO	Light Fuel oil	Light fuel oil
HFO	Heavy fuel oil	High sulphur fuel oil Low sulphur fuel oil
NAPHTA	Naphtha	
OTHPETRO	Other petroleum products	Liquefied petroleum gas
NATGAS	Natural gas	Natural gas
OTHGAS	Derived gas	Natural gas
WASTE	Industrial and municipal waste	
BIOGASOL	Biogasoline also including hydrated ethanol	Premium leaded gasoline Premium unleaded 95 RON Premium unleaded 98 RON Regular unleaded gasoline Regular leaded gasoline
BIODIESEL	Biodiesel	Automotive diesel
BIOGAS	Biogas	Natural gas
OTHRENEW	Other combustible renewables	
ELECTR	Electricity	Electricity
HEATPROD	Heat	
NUCLEAR	Nuclear	
HYDRO	Hydroelectric	
GEOTHERM	Geothermal	
SOLAR	Solar	
WIND	Wind power	
OTHSOURC	Other sources	
LOSS	Distribution losses	

Note: grey font indicates energy carriers excluded from further analysis.