Are Armington elasticities different across countries and sectors? A European study[†]

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Zoryana Olekseyuk, Hannah Schürenberg-Frosch[*]

Abstract

CGE models are widely used for policy evaluation and impact analysis. The modeling technique is especially useful in the analysis of trade reforms, tax reforms, energy sector reform and development policy analysis. However, the results of such models are often argued to be sensitive to the choice of exogenous parameters such as trade elasticities. Several authors show that the choice of the so-called Armington elasticities in the import demand function has a strong influence on the simulation results. Most existing estimates of Armington elasticities are only for the U.S. The few studies for other countries find substantially differing results. Nevertheless, many CGE modellers simply adopt the elasticities from the literature. This paper aims at providing estimated elasticities based on recent data for a larger group of European countries. Using cointegration analysis and panel fixed effects analysis we estimate the first order condition resulting from cost minimization or utility maximization subject to the CES subutility or cost function in imports and domestic goods. The results show a rather large variance across sectors and countries, and the magnitude is only partly comparable to the U.S. elasticities.

JEL classification: F14, C68, F17

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[*]both: University of Duisburg-Essen, Chair of International Economics, Institute for Economics and Business Administration, Universitätsstr. 12, D-45117 Essen, zoryana.olekseyuk@ibes.uni-due.de, hannah.schuerenberg-frosch@uni-due.de. The authors thank Volker Clausen for helpful comments and suggestions.

1 Introduction

CGE models are a widely used and accepted technique for policy evaluation and impact analysis. The modelling technique is especially useful in the analysis of trade reforms, tax reforms, energy sector reform and development policy analysis. However, the results of such models are often argued to be sensitive to the choice of exogenous parameters such as elasticties. Apart from the elasticities of substitution between production factors in the production function, the so-called Armington elasticities which determine the substitutability between domestic goods and imports are often mentioned as one of the caveats of CGE models. McDaniel & Balistreri [2002], Schuerenberg-Frosch [2012], Siddig & Grethe [2012] and others show that the choice of the Armington elasticities in the import demand function has a strong influence on the simulation results. Hence, it is very important to choose these elasticities appropriately. Unfortunately, many CGE papers are not very transparent concerning the choice of elasticities and the sensitivity of the results with respect to this choice. As e.g. Welsch [2008] points out "In practice, the elasticities employed are frequently based on 'guestimation' or on estimates picked from the literature."

There exist a number of estimations for Armington elasticities and the results of these are frequently used in CGE studies. This paper argues that this strategy could lead to severely biased model results as the estimated elasticities might not be applicable to either the specific model or country in question. The reasons are the following:

Most existing studies provide results only for the US. Even among the estimated elasticties for the US there is some variance found. More importantly, the few studies for other countries [such as Gibson, 2003; Welsch, 2006, 2008] find substantially differing results. But studies for other countries are very scarce. Thus, the often formulated argument that time-series studies find rather small elasticities might simply be driven by rather small elasticities in the specific US case.

One result that emerges quite clearly from the literature is that elasticities differ depending on the level of aggregation used in the data. It is uniformly found across most studies that elasticities tend to be higher the more disaggregate the underlying data is. Thus, a CGE modeler ought to use estimated elasticities from a study with the same level of sectoral disaggregation he uses in his model. However, the mentioned studies for the US have a rather high level of disaggregation with 180-200 industries included. Most CGE studies are much more aggregate. Nonetheless, as McDaniel & Balistreri [2002] point out, authors simply calculate the average elasticity across subsectors and use this number for their aggregated sector. This might lead to an aggregation bias and thus to biased CGE results.

Welsch [2006] argues that the Armington elasticities decrease over time due to intra-industry specialization among open economies. He also finds indications for this hypothesis in French data. Thus, elasticities from older studies (e.g. from the 1990s or earlier) might not be useful in models based on more recent data as the trade pattern and trade motives might have undergone important changes since then.

Blonigen & Wilson [1999] investigate the determinants of Armington elasticities. In addition to sector-specific effects they also find country-specific determinants such as trade policy. This implies that the use of elasticities from another country might be misleading.

In addition, a comparison of estimated elasticities across countries is very difficult as the studies often not only differ in the country but also in the degree of disaggregation, the method applied, the time horizon, the data frequency and even the underlying structural model.

This paper aims to provide additional insights in the aforementioned aspects by providing estimated elasticities based on recent data for a larger group of European countries. We focus here on elasticities for CGE modeling. Thus, we aggregate our data to the same level as used in most CGE applications. We also derive our functional form from these models.[1] We then make comparisons across the different countries in order to analyze whether and to which extent the usage of elasticities from another country is possible.

2 Literature review

McDaniel & Balistreri [2002] show in a simulation exercise that the choice of the elasticity might be crucial in determining welfare gains or losses from a given policy reform. They find that even a qualitative switch in the overall welfare result is possible by changing the Armington elasticity. Schuerenberg-Frosch [2012] shows by drawing elasticities randomly from a uniform distribution that even though the quantity variables are robust, price results are quite sensitive with respect to the elasticity set. A similar approach is used by Frey & Olekseyuk [2011] with comparable results.

Several studies have estimated Armington elasticities since the 1970s, summaries of the literature can be found for instance in McDaniel & Balistreri [2002] and Welsch [2008]. We focus here on the most recent findings on the size and determinants of Armington elasticities. The most striking impression from the literature study on estimated Armington elasticities is that the overwhelming majority of time series estimations with dis-

[1] We do explicitly not consider the studies and methods based on partial trade models. A very profound reasoning why these are not transferable to a CGE setting is provided by McDaniel & Balistreri [2002].

aggregated industries are for the United States. Only very few time series analysis exist for other countries as also Welsch [2008] points out. Recent examples for the US are Reinert & Roland-Holst [1992] and Gallaway *et al.* [2003].

Most generally the Armington estimates available can be grouped as follows: There exist single-country time series studies, and a limited number of cross-sectional or panel studies. In addition, one needs to distinguish between those studies that estimate a CES function which is basically derived from a corresponding CGE model and those that estimate a multi-equation trade model. While some studies estimate the so-called 'macro'-elasticity, i.e. the elasticity of substitution between domestic and foreign goods other estimate the 'micro'-elasticity which is the elasticity of substitution between different countries of origin. Few studies follow a nested approach and estimate both. Moreover studies differ in the frequency of the data and degree of sectoral disaggregation used as well as in the econometric procedure applied. To sum up, even though there exists quite a number of studies in the field, results are hardly comparable across these studies - a point also made by McDaniel & Balistreri [2002]. Nonetheless, many authors make this exact comparison.

Following McDaniel & Balistreri [2002] some general findings emerge from the literature:

1. Long-term elasticities are larger than short-term elasticities. This point is indeed found by most authors even though using quite substantially differing approaches to reach this conclusion. The studies by Gallaway *et al.* [2003], Welsch [2006, 2008] and Németh *et al.* [2011] use error correction models and thus explicitly estimate a short-term and a long-term relationship for each sector. Gibson [2003], in contrast, comes to the same conclusion by comparing results obtained with quarterly data and annual data. This finding is very intuitive given that the reaction to changes in relative prices might be rather slow due to high adjustment costs.

2. The 'micro'-elasticity which determines the ease of substitution between foreign goods of different origins is much higher than the 'macro'-elasticity between domestic and foreign goods. This point, too, is quite intuitive especially in the context of a large gap in technology between the respective country and its trading partners. McDaniel & Balistreri [2002] argue that some authors confuse these elasticities and compare results for the one with results for the other. This stylized fact can be found both by comparing studies that only estimate the macro elasticity (like e.g. Shiells & Reinert [1993], Reinert & Roland-Holst [1992], with studies that only estimate the micro elasticity. The finding is confirmed by studies that follow a two-stage-procedure and estimate the nested-CES-function like Németh *et al.* [2011] and Feenstra *et al.* [2012].

3. The estimated elasticities increase with the degree of disaggregation in the data.

Again, a very intuitive finding, as more disaggregate data contains sectors that are more homogeneous in the produced goods and thus also higher in their international substitutability. This phenomenon is generally considered as an "aggregation bias". While this might be true in the econometric context, if the estimated elasticities are to be used for a CGE model, the problem is somewhat more complex. The aggregation in the data used for estimation should, in our view, match the disaggregation that will be used in the respective CGE model. Hence, while the estimated elasticities at a 2-digit-level might be to low for the use in a very disaggregate trade model, they might however be more convenient for a rather aggregated CGE model - a point which is also made by Welsch [2006]. Given that this aggregation problem has been confirmed by many studies, one should, as McDaniel & Balistreri [2002] point out, be cautious in using elasticities from a very aggregate estimation in a more disaggregate setup or vice versa. However, this is a common practice.

4. Many authors argue that elasticities in time-series studies are smaller those those resulting from "cross-sectional" studies. However, this conclusion can be questioned. First of all, most time-series estimations refer to the US while cross-sectional studies partly only cover Europe. Hence, the US might as well just be an outlier and the average elasticity in larger cross-sections is simply higher because also the single-country elasticities would be higher if they would have been investigated. An indication for this fact can be found in Gibson [2003] who finds at least for South Africa considerably higher elasticities in a time-series study. Note that the definition of "cross-sectional" is not the same across studies. Some have the cross-sectional dimension "trading partner" while others estimate across sectors and a third group uses a cross-section of importing countries. Thus, some in fact estimate the 'micro' elasticity, some estimate the 'macro' elasticity and some estimate a cross-sectoral average elasticity per country which should be highly biased if an aggregation bias exists. Nonetheless, the fact that the US time series estimations lead to considerably lower results compared to alternative approaches should not be ignored and will be part of our focus in this paper.

McDaniel & Balistreri [2002] raise another question which concerns the correspondence between the econometric model and the CGE model. Some authors such as Erkel-Rousse & Mirza [2002] argue that the results of a single equation estimation directly estimating the CES-function are biased as the resulting elasticity also includes the supply elasticity. These authors use a system of equations based on a trade model. Nonetheless, the CES function which is used in most of the studies directly stems from the CGE models in which the Armington elasticity will be employed. Thus, even though the estimates from a direct estimation of the CES function might be biased both due to the left-out supply side and due to a rather high degree of sectoral aggregation they might still be the best possible study design for the Armington elasticity in CGE models.

Most time series studies, especially those for the US, use 3-digit-level data i.e. between 150 and 200 sectors and employ either a simple OLS, an OLS with lagged endogenous variables or, more recently, error correction approaches as the variables are typically integrated. Examples for time-series approaches are Reinert & Roland-Holst [1992], Shiells & Reinert [1993], Gallaway *et al.* [2003] and Blonigen & Wilson [1999] for the US, [Kapuscinski & Warr, 1996] for the Philippines, Gibson [2003] for South Africa and Welsch [2006] for France. Saito [2004], Welsch [2008] and Németh *et al.* [2011] provide panel data results. The panel studies typically use a much higher aggregation with only 6-15 sectors. The elasticities found in panel studies are slightly smaller than those found in time-series studies thus contradicting the argument that cross-sectional studies per se obtain higher results.

This paper tries to shed light on observable patterns in estimated elasticities by comparing the macro elasticity obtained from a 2-digit-level data set (which is the degree of disaggregation also used in EU and OECD SAMS and thus used in many CGE studies for these countries) across European countries. We try to fill two gaps in the literature. 1.) Provide estimated elasticities for a number of countries outside the US and 2.) See whether it is acceptable to use estimated elasticities for another country when specifying a CGE model - which is very often done in practical CGE work.

3 Theoretical background

In his seminal paper "Theory of Demand for Products Distinguuished by Place of Production" Armington [1969] developed the theoretical basis used as modeling approach for import demand in most CGE studies. Armington assumes that product varieties from different places of production are imperfect substitutes. Thus consumers will at the same time consume home and foreign varieties of the same good. Their demand for the different varieties will depend on the so-called Armington elasticity. The Armington elasticity will be lower, the higher the perceived difference between the varieties.

The CES subutility function for imports in the named models is normally assumed to be:

$$U(M,D) = \alpha \left[\beta\, M^{\frac{\sigma-1}{\sigma}} + (1-\beta)\, D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where α and β will be calibrated from base year data and σ denotes the constant elasticity of substitution between imports (M) and domestic supply (D).

Utility maximization yields the following first-order condition:

$$\frac{M}{D} = \left[\left(\frac{\beta}{1-\beta}\right)\left(\frac{p_D}{p_M}\right)\right]^{\sigma}, \tag{2}$$

where p_D and p_M denote the prices of the domestic and foreign variety respectively. Taking equation (2) in natural logarithms leads to the regression function:

$$ln\left(\frac{M}{D}\right) = \sigma\, ln\left(\frac{\beta}{1-\beta}\right) + \sigma ln\left(\frac{p_D}{p_M}\right), \tag{3}$$

where the Armington elasticity can be derived directly from the estimated coefficient of the price relation between domestically produced and imported varieties.

4 Econometric specification and data

This paper estimates equation (3) for the manufacturing sectors of seven European countries. The econometric procedure is as follows:

4.1 Data sources and limitations

The existing studies differ significantly in both the frequency of the data used and in the degree of sectoral disaggregation. Our paper aims at providing guidance on the choice of elasticities in the CGE modeling context. Hence, given that the majority of CGEs is calibrated based on yearly data and mainly interpreted to provide insights on medium term developments, we run our regressions based on yearly data, even though this strongly limits data availability. However, as other studies have shown significant differences between long-term and short-term elasticities we stick with our choice of yearly data in order to prevent a downward bias in our results due to the use of quarterly data.

We combine data from two sources: Production data stems from OECD's STAN database which comprises production data both in current and constant prices for 32 OECD countries in ISIC Rev. 3 classification until the year 2009 and for 15 countries in ISIC Rev. 4 up to the year 2011. We need both time series in order to compute the price deflator series. As the STAN database does not comprise data on imports at constant prices, we used data from EUROSTAT's PRODCOM database for the import and export variables. The PRODCOM data is only available from 1995 onwards and only covers the manufacturing sectors, hence we had to limit our analysis to these sectors and years as other data sources with sufficient sectoral detail, comparable sector classification and coverage of both values and volumes were not available.

Table 1 describes the two data sources. It shows that the PRODCOM data covers much

Table 1: Database properties

Indicator	Source	Sector coverage	Period coverage
production at current prices (PROD)	OECD STAN	ISIC 01-99	1970 - 2009/2011
production at constant prices (PRODK)	OECD STAN	ISIC 01-99	1970 - 2009/2011
Imports value (IMP_VAL)	PRODCOM	NACE Rev. 1.1 10-40	1995-2011
Imports quantity (IMP_Q)	PRODCOM	NACE Rev. 1.1 10-40	1995-2011
Exports value (EXP_VAL)	PRODCOM	NACE Rev. 1.1 10-40	1995-2011
Exports quantity (EXP_Q)	PRODCOM	NACE Rev. 1.1 10-40	1995-2011

less years and sectors compared to the STAN data. In addition, for some countries, esp. new EU member countries, the time series only start in 2001. For other countries the constant price data in STAN was incomplete or not available. Hence, we were only able to calculate the required data for 9 countries and a subset of 18-21 sectors. Nevertheless, this is, to our knowledge, the broadest coverage ever included in an analysis of Armington elasticities for European countries.

4.2 Data transformation

The estimation of equation (3) requires data for the relation between imports and domestic supply in quantity terms as well as for the price relation. These data are not readily available in any public data source and the data in constant and current prices from OECD STAN are also not directly comparable to the data in volumes and quantities from PRODCOM. We took the following steps to calculate the required series.

1. Imports and exports from PRODCOM were initially available in quantity and value terms. We first calculated unit prices based on the two series.
2. We then calculated imports and exports in constant terms and choose the base year in accordance to the base year in OECD STAN for the respective country.
3. We then calculate the import and export price deflator, which will be used as price proxy variable in our regression.
4. The production data was readily available in current and constant terms. However, we need data for domestic supply instead of domestic production. Hence, we cal-

culated domestic supply as *Domestic supply = Domestic production + Imports - Exports*. This measure was calculated both in current and constant terms as well as the resulting price deflator which serves as a proxy for the domestic price.

As a result we have a dataset which covers 4 countries (Belgium, Czech Republic, Denmark and Greece) in ISIC Rev. 3 sector classification and 5 countries (Austria, Finland, France, Hungary and Italy) in ISIC Rev. 4 sector classification. The data and sector coverage are shown in table 2.

Table 2: Data coverage

country	**sectors**	**years**
ISIC Rev. 3		
Belgium	15, 17-18, 20, 22-25, 27-36	1995-2009
Czech Republic	15-36	2001-2009
Denmark	15-33, 35-36	1995-2007
Greece	13-15, 17-27, 29-33, 36	1995-2009 (incomplete)
ISIC Rev. 4		
Austria	09-13, 16-17,19-20, 22-30	1995-2011
Finland	9-11, 13-17, 20, 22-26, 28, 30	1995-2011
France	9-29	1995-2011 (incomplete)
Hungary	16-17, 20-30	2001-2010
Italy	16-28, 30, 33	1995-2010

4.3 Time series properties

We conduct unit root tests to check whether the underlying time series are stationary or integrated. This step is important as a regression with non-stationary time series may lead to spurious regression with significant parameters and high values for the coefficient of determination even if the variables are not correlated. Hereby, a time series is non-stationary if the mean and autocovariances of the series depend on time. If time series are stationary in the first or second differences (i.e. integrated of order one or two), it is possible to estimate a cointegration relationship. According to Engle & Granger [1987], two variables are cointegrated if they are integrated with the same order and there exists a linear combination of the two series which is integrated with lower order than the series.

Following the Engle-Granger methodology, the residuals from an OLS estimation with time series integrated of order one have to be stationary in case of cointegrated variables.

The results for Augmented Dickey-Fuller (ADF) tests are shown in tables A.8 and A.9. We test all the time series as well as the residuals for a unit root in the level, first and second difference with different specifications in the test equation: including a constant, including a constant and a linear trend, and excluding the both. Most time series are non-stationary, but integrated of order one or two. We hence run regressions for each sector in each country where the requirements of the Engle-Granger-procedure are met (i.e. same order of integration for both series) and for those series which are stationary.

The corresponding residuals from the OLS estimations are stationary only for some sectors in each of the countries. For instance, for Greece we find a cointegrating relationship in such sectors as food products and beverages, paper and paper products, rubber and plastic products and others.

We suspect that the non-stationarity of the OLS residuals is mainly driven by the short time series for single sectors and countries as the number of observations varies between 9 for Czech Republic and 17 for Finland what implies a poor accuracy of stationarity and integration tests.

4.4 Econometric procedure

For sectors which possess initially stationary or cointegrated time series we estimate equation (3) using OLS following the above-mentioned Engle-Granger-procedure for integrated time series. The results will be shown in the next section. However, due to the rather small number of observations per sector, we are often not able to clearly identify a cointegrating relationship at the sectoral level. As this leads to exclusion of many available sectors for every country due to the test result of non-stationary and not cointegrated time series, we try to increase the number of observations and hence, the accuracy of both the estimation and the test statistics, by pooling the data over comparable (i.e. neighbouring) sectors. A comparable strategy has been chosen by Welsch [2008].

Table 3: Sector pooling

ISIC Rev.3		
	single sector	pooled sector
17	Textiles	Textiles, clothing and leather products
18	Wearing apparel	
19	Leather and related products	
20	Wood and cork products	Wood and paper products
21	Paper and paper products	
23	Coke, refined petroleum products and nuclear fuel	Coke, petroleum, fuel and chemicals
24	Chemicals and chemical products	
25	Rubber and plastics products	Rubber, plastics and non-metallic products
26	Other non-metallic mineral products	
29	Machinery and equipment	Machinery
30	Office, accounting and computing equipment	
31	Electrical machinery and apparatus	
34	Motor vehicles, trailers and semi-trailers	Transport vehicles and equipment
35	Other transport equipment	

ISIC Rev.4		
	single sector	pooled sector
10	Food products	Food, beverages, tobacco
11	Beverages	
12	Tobacco products	
13	Textiles	Textiles, clothing and leather products
14	Wearing apparel	
15	Leather and related products	
16	Wood and cork products	Wood and paper products
17	Paper and paper products	
19	Coke and refined petroleum products	Coke, petroleum, chemicals and pharmaceutical products
20	Chemicals and chemical products	
21	Basic pharmaceutical products and preparations	
22	Rubber and plastics products	Rubber, plastics and non-metallic mineral products
23	Other non-metallic mineral products	
24	Basic metals	Metals and fabricated metal products
25	Fabricated metal products	
26	Computer, electronic and optical products	Electronic, computer, optical and electrical equipment
27	Electrical equipment	

We pool comparable industries to broader groups (see Table 3) with the aim to increase the degrees of freedom and to obtain further reliable estimates for the Armington elasticities. The approach to combine information from the time series dimension with the cross-sectional one is often used in cases with short time series which are available across a cross-section of units such as countries, regions, firms or industries.[2]

[2]See Banerjee [1999], Baltagi & Kao [2000].

As the pooled sectors include several single industries we implement a panel fixed effects analysis accounting for individual effects. As we expect a contemporaneous correlation between the single industry residuals we use corrected White cross-section standard errors [See White, 1980] to allow for non-zero covariances across cross-sections clustered by period. The procedure of OLS estimation combined with bias correction for the auto-correlated disturbances is common place in panel analysis according to Arellano [1987], Moulton [1986] and Hansen [2007]. Kezdi [2005] demonstrates that finite samples with a low number of observations can be used for panel analysis if standard error correction is used in case of serial correlation in the error process.

5 Results

5.1 Single-sector cointegration analysis

The analysis of the time series properties showed that for most countries both the price and quantity ratio series are non-stationary, but integrated of order one or two. This implies the risk of spurious regression meaning that non-stationary and not cointegrated time series may lead to significant coefficients for the Armington elasticity without any economic meaning. Hence, we perform simple time series OLS estimations only for those sectors of the eight[3] European countries which possess initially stationary or cointegrated time series. Moreover, the restricted data availability[4] reduces the number of estimates further. For instance, for Hungary there is data for only 13 sectors with 10 observations available which is not enough to estimate all industry-level elasticities. We cannot present any estimates for Belgium as the time series for all sectors are non-stationary and obviously not cointegrated being integrated of different orders. Therefore, we present here the estimated coefficients for sectors with available data and stationary or cointegrated time series. These implications allow us to estimate 7 elasticities for Finland, Austria, Denmark and Greece, while for France and Italy only 3 coefficients can be obtained.

Tables 4 and 5 summarize the OLS coefficient estimates for all countries and sectors with stationary or cointegrated time series in the different revisions of the ISIC classification. Only 17% of all estimates are insignificant. Those are the elasticities for wood and rubber products in Czech Republic, other non-metallic mineral products in Denmark and France, computer, electronic and optical products in Hungary, wearing apparel in Finland as well as for coke and refined petroleum products in Austria. The significant estimates are between 0.30 and 3.67 which is a plausible magnitude, when compared to results in the literature. Moreover, only 2 of the significant elasticities are negative (for food prod-

[3] For Belgium we could not clearly determine the time series properties and have thus excluded it from all the regressions shown.

[4] See Table 2.

ucts in Finland and Austria), what lends some support to the validity of the obtained results which are comparable with other recent studies. For instance, Gibson [2003] find for South Africa for 32 out of 42 industries positive and significant short-run Armington elasticities in the range between 0.42 and 2.77. For the Philippines Kapuscinski & Warr [1996] obtain estimates between 0.20 and 4.00. However, only half of their coefficients are positive and significant. Welsch [2008] derives elasticities for four European countries[5] and 17 sectors with values between 0.04 and 3.68. In his study 64% of all estimates are significant at the 5% level and there are 8 negative estimates out of 53 coefficients.

Our results indicate a rather large variation across sectors and countries. In particular, the country averages over all sectors vary from 0.68 in the Czech Republic to 1.91 in Finland. There are also strong differences in the variance of the industry-specific elasticities among the European countries. While the estimates for Finland and Austria lie in the interval rather broad intervals from 0.60 to 2.95 and 3.67 respectively, the values for Denmark show a much smaller range between 0.88 and 1.42 or for Italy even between 0.93 and 1.31. Such differences also occur for particular sectors. For instance, the estimated values for beverages vary from 1.90 in Finland to 3.67 in Austria. The same applies to computer, electronic and optical products where the elasticities lie between 0.60 in Finland and 1.31 in Italy, and to publishing, printing and reproduction of recorded media with values from 0.71 in Greece to 1.06 in Denmark. Somewhat minor differences across countries are found for non-metallic mineral products (from 0.94 in Italy to 1.25 in Austria) and for other transport equipment (from 1.13 in Denmark to 1.42 in Czech Republic).

Generally speaking, we find smaller elasticities of substitution between imported and domestic goods for sectors with lower value added (processing of raw materials and agricultural products and basic manufacturing) while elasiticites are higher in sectors with higher value added (more elaborate manufacturing and technology). In particular, the elasticity for mining support activities in Austria is 0.61 while the value for motor vehicles, trailers and semi-trailers is higher with 1.37. The estimate of 0.30 for coke and petroleum products in Czech Republic is much lower than the elasticity for other transport equipment with the value of 1.42. This implies that substitutability of low-level processed goods, such as primary and consumer products, is lower compared to investment and high value-added goods. This finding is consistent with Saito [2004], who estimates Armington elasticities between 0.90 and 3.50 for 14 OECD countries and 10 sectors with higher values for machinery and investment goods compared to for consumption goods.

[5]Germany, France, Italy and United Kingdom.

Table 4: Single-sector results for ISIC Rev. 3 classification

	ISIC Rev. 3 Sector	Czech Republic Coeff.	R^2	Denmark Coeff.	R^2	Greece Coeff.	R^2
13	Mining of metal ores	-	-	-	-	-	-
14	Other mining and quarrying	-	-	-	-	-	-
15	Food products and beverages	-	-	-	-	1.30*** [8.68]	0.85
16	Tobacco products	-	-	1.32*** [13.01]	0.94	-	-
17	Textiles	-	-	1.42*** [4.89]	0.69	-	-
18	Wearing apparel	-	-	-	-	1.21*** [5.26]	0.68
19	Leather and related products	-	-	-	-	-	-
20	Wood and cork products	0.02 [0.10]	0.00	1.15*** [21.84]	0.98	-	-
21	Paper and paper products	-	-	-	-	1.44*** [6.97]	0.79
22	Publishing, printing and reproduction of recorded media	-	-	1.06*** [22.28]	0.98	0.71*** [6.04]	0.74
23	Coke, refined petroleum products and nuclear fuel	0.30* [2.14]	0.40	-	-	-	-
24	Chemicals and chemical products	-	-	0.88*** [5.62]	0.74	-	-
25	Rubber and plastics products	0.56 [1.23]	0.18	-	-	0.89*** [9.95]	0.88
26	Other non-metallic mineral products	-	-	0.57 [0.84]	0.06	-	-
27	Basic metals	-	-	-	-	1.05*** [3.61]	0.50
28	Fabricated metal products	-	-	-	-	-	-
29	Machinery and equipment	-	-	-	-	0.92*** [34.56]	0.99
30	Office, accounting and computing equipment	-	-	-	-	-	-
31	Electrical machinery and apparatus	-	-	-	-	-	-
32	Radio, television and communication equipment	-	-	-	-	-	-
33	Medical, precision and optical instruments	-	-	-	-	-	-
34	Motor vehicles, trailers and semi-trailers	1.10*** [63.25]	1.00	-	-	-	-
35	Other transport equipment	1.42*** [6.99]	0.88	1.13*** [11.12]	0.92	-	-
36	Furniture, other manufacturing	-	-	-	-	-	-

***, **, * indicates significance at the 1%, 5% and 10%-Level respectively.

Table 5: Single-sector results for ISIC Rev. 4 classification

ISIC Rev. 4	Sector	Finland		France		Italy		Hungary		Austria	
		Coeff.	R^2	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
9	Mining support service activities	-	-	-	-	-	-	-	-	0.61** [2.29]	0.26
10	Food products	-2.04*** [-6.16]	0.72	-	-	-	-	-	-	-2.37*** [-6.23]	0.72
11	Beverages	1.90*** [11.92]	0.91	-	-	-	-	-	-	3.67*** [5.88]	0.70
12	Tobacco products	-	-	-	-	-	-	-	-	-	-
13	Textiles	-	-	1.20*** [13.11]	0.93	-	-	-	-	-	-
14	Wearing apparel	-2.86 [-1.11]	0.08	-	-	-	-	-	-	-	-
15	Leather and related products	-	-	-	-	-	-	-	-	-	-
16	Wood and cork products	2.12*** [6.34]	0.73	-	-	-	-	-	-	-	-
17	Paper and paper products	2.95*** [17.71]	0.95	-	-	-	-	-	-	-	-
18	Printing and reproduction of recorded media	-	-	-	-	1.01*** [4.20]	0.56	-	-	-	-
19	Coke and refined petroleum products	-	-	-	-	-	-	-	-	0.81 [1.68]	0.16
20	Chemicals and chemical products	0.87*** [4.81]	0.61	-	-	-	-	-	-	-	-
21	Basic pharmaceutical products and preparations	-	-	-	-	-	-	-	-	-	-
22	Rubber and plastics products	-	-	-	-	-	-	-	-	0.78*** [4.45]	0.62
23	Other non-metallic mineral products	-	-	0.70 [1.25]	0.10	0.93*** [16.96]	0.95	-	-	1.25*** [10.16]	0.87
24	Basic metals	-	-	-	-	-	-	-	-	-	-
25	Fabricated metal products	-	-	-	-	-	-	1.03*** [27.49]	0.99	-	-
26	Computer, electronic and optical products	0.60** [2.47]	0.34	-	-	1.31*** [8.85]	0.85	0.20 [0.51]	0.03	-	-
27	Electrical equipment	-	-	-	-	-	-	-	-	-	-
28	Machinery and equipment	-	-	-	-	-	-	-	-	-	-
29	Motor vehicles, trailers and semi-trailers	-	-	1.46*** [74.38]	1.00	-	-	-	-	1.37*** [18.66]	0.97
30	Other transport equipment	-	-	-	-	-	-	-	-	-	-
33	Repair and installation of machinery and equipment	-	-	-	-	-	-	-	-	-	-
35	Electricity, gas, steam and air conditioning supply	-	-	-	-	-	-	-	-	-	-
36	Water collection, treatment and supply	-	-	-	-	-	-	-	-	-	-

***, **, * indicates significance at the 1%, 5% and 10%-Level respectively.

5.2 Panel fixed effects analysis

Given the rather small amount of reliable results from single-sector OLS estimation, we move on to pooled fixed effects estimations across comparable sectors in order to increase the number of observations (i.e. the number of degrees of freedom) and thus the accuracy of the results and the test statistics. Pooling the data over 2-3 sectors implies, of course, a loss in the level of disaggregation. However, we consider the results as more reliable. In addition, panel estimates may also serve as a robustness check for the single-sector cointegration analysis. We use corrected standard errors, clustered by period to control for contemporary correlation among residuals.

The panel estimation results are given in Table 6 and 7. As with single-sector estimations only 17% of all estimated coefficients are insignificant, this includes the elasticities for food and beverages in France and Austria; rubber, plastics and non-metallic products in France, Hungary and Denmark; textiles, clothing and leather products in Czech Republic and electronic, computer and optical equipment in Hungary.

The use of panel fixed-effects OLS increases the quality of our estimations as we obtain no negative elasticities among the significant coefficients. Furthermore, according to the redundant fixed effects test all estimations, except for wood products in Finland and rubber products in France, deliver significant cross-section fixed effects. The Jarque-Bera statistic indicates that the estimated residuals are normally distributed.[6]

As pooling of comparable 2-digit commodity groups of ISIC leads to an increased variety of individual goods inside a group, the substitutability between domestic and foreign varieties declines in comparison with the single-sector 2-digit level results. We observe that all significant estimates lie now in the interval between 0.32 and 2.43 compared to the maximum value of 3.67 before. The highest country average across sectors is found for Finland with the value of 1.65 which is lower than the Finnish average found above.

[6] Jarque-Bera test results not shown here for convenience. For the sake of completeness: The null hypothesis of normally distributed residuals is rejected for coke, petroleum and chemicals in Austria and Italy; electronic, computer and optical products in Austria; textiles, clothing and leather products in Finland and France; wood and paper products in Finland and Italy.

Table 6: Panel fixed effects results for ISIC Rev. 3 classification

ISIC Rev. 3	Czech Republic			Denmark[a]			Greece[b]		
Pooled series	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs
Textiles, clothing and leather products	1,285*** [12,650]	0,753	27	-0,725 [-1,696]	0,602	26	1,329*** [20,606]	0,739	45
Wood and paper products	0,624** [2,147]	0,881	18	1,147*** [22,699]	0,925	26	1,176*** [34,913]	0,914	30
Coke, petroleum, fuel and chemicals	0,316** [2,839]	0,912	18						
Rubber, plastics and non-metallic products	0,673*** [3,966]	0,779	18	-0,053 [-0,153]	0,653	26	0,954*** [23,672]	0,993	30
Machinery	0,995*** [17,828]	0,933	27	1,011*** [19,516]	0,992	37	0,914*** [31,219]	0,993	27
Transport vehicles and equipment	1,117*** [67,507]	0,979	18						

[a] Textiles and clothing, except leather products

[b] Machinery, except office and computing equipment

***, **, * indicates significance at the 1%, 5% and 10%-Level respectively.

Table 7: Panel fixed effects results for ISIC Rev. 4 classification

ISIC Rev. 4	Finland[a]			France			Italy			Hungary[b]			Austria[c]		
Pooled series	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs	Coeff.	$\overline{R}^2$	# Obs
Food, beverages, tobacco	1,465*** [13,682]	0,559	34	0,161 [0,800]	0,985	36							-0,081 [-0,134]	0,227	51
Textiles, clothing and leather products	1,620*** [5,148]	0,394	50	1,120*** [10,398]	0,767	40									
Wood and paper products	2,433*** [12,205]	0,804	34	0,954*** [8,350]	0,917	24	1,103*** [9,392]	0,866	32	1,068*** [7,807]	0,964	20	1,391*** [7,475]	0,746	34
Coke, petroleum, chemicals and pharmaceutical products				1,229*** [16,727]	0,912	51	1,331*** [12,878]	0,944	48	1,025*** [21,829]	0,925	20	0,829** [2,476]	0,994	34
Rubber, plastics and non-metallic mineral products	1,125*** [12,106]	0,951	32	0,079 [0,230]	0,016	28	0,796*** [10,882]	0,774	32	0,326 [0,876]	0,542	20	0,867*** [6,753]	0,871	31
Metals and fabricated metal products	1,619*** [5,090]	0,723	34	1,096*** [16,766]	0,975	24	0,840*** [10,548]	0,987	32	1,125*** [14,833]	0,925	20	1,182*** [9,780]	0,628	34
Electronic, computer, optical and electrical equipment							0,924*** [26,675]	0,972	32	0,045 [0,152]	0,392	20	0,819*** [3,957]	0,420	28

[a] Food and beverages, except tobacco
[b] Chemicals and pharmaceutical products, except coke and petroleum
[c] Coke, petroleum and chemicals, except pharmaceutical products

***, **, * indicates significance at the 1%, 5% and 10%-Level respectively.

The pooled estimates also indicate a reduced variance in the sector-specific elasticities for each of the European countries. In particular, the coefficients for Finland are only between 1.13 to 2.43, for Czech Republic - between 0.32 and 1.29, while the smallest interval is found for Hungary: from 1.03 to 1.13 only. Anyway, we still find quite large differences between the industry-level estimates across the European countries. The Armington elasticity for wood and paper products varies from 0.62 in Czech Republic to 2.43 in Finland. For metals and fabricated metal products we obtain the estimates in the range from 0.84 in Italy to 1.62 in Finland and for rubber, plastics and non metallic mineral products the values are between 0.80 in Italy and 1.13 in Finland. Somewhat smaller differences can be observed for coke, petroleum and chemicals (from 0.83 in Austria to 1.33 in Italy) as well as for machinery (from 0.92 in Greece to 1.01 in Denmark).

The presented pooled estimates are somewhat lower compared to the results of Welsch [2008] who also pooles comparable 2-digit sectors to some extent. Hence, only a generic comparison is possible as the country samples overlap only for France and Italy. Nevertheless, Welsch [2008] finds an Armington elasticity of 1.495 for textiles, clothing and leather products in France while our coefficient amounts to 1.12. The same can be observed for rubber and plastic products in Italy where our elasticity is lower with 0.80 than the value of 2.22 in the aforementioned study. These differences occur mostly due to the slightly different econometric specification used and another time horizon (1979-1990) of the underlying data.

Our results differ also from the estimated Armington elasticities for the US in the 1980s and 1990s. Reinert & Roland-Holst [1992] estimate the elasticities for 163 sectors in the interval from 0.14 to 3.49 while Gallaway *et al.* [2003] obtain estimates for 306 commodity groups ranging between 0.52 and 4.83 with a long-run average of 1.55. Even though the estimated values by Reinert & Roland-Holst [1992] are spread in a rather wide interval, the majority of their coefficients are between 0 and 1 what is lower than our estimates. Taking into account the high level of disaggregation (e. g. 4-digit SIC) in the cited study this is surprising as a higher degree of disaggregation is normally associated with higher substitutability. The rather low US elasticities might be a distinct feature of the US economy, however, the higher elasticities for other countries outside the USA[7] could partly be explained by the fact that the non-US studies are more recent and thus include the effects of increased international market integration and increasing competition which both lead to higher substitutability between domestic and foreign goods.

To sum up, our estimates lie within the interval that has emerged from other studies and thus seem to be reliable. However, if investigated in more detail than just comparing

[7]See also Gibson [2003] for South Africa.

the averages and the spread of the results, non-negligible differences among sectors within one country as well within one sector across countries are found. These cross-country and cross-sectoral differences in the Armington elasticities reflect diverging preferences of consumers with respect to domestic and foreign goods in different states. In addition, differences in the specification of the studies may also explain diverging results. As the elasticities capture the substitutability between imports and domestic goods, which is determined by the degree of product similarity a higher degree of aggregation leads to lower similarity within one group. Hence, in more aggregated setups, the elasticities should be lower. Keeping this in mind our estimates are surprisingly high compared to other studies given our highly aggregated commodity groups. The composition within one of our sectors at home and abroad, thus we would have expected rather low elasticities of substitution. In addition, the estimates also reflect the availability of domestic and foreign goods which may be restricted as a result of protectionist and regulation measures in single countries and sectors. Hence, studies with rather low elasticities might have a higher degree of protection. Another difference in the specification simply lies in the time horizon. Most of the mentioned studies for the US use data from the 1970s or earlier whereas most of the studies investigating countries outside the US use more recent data. It is well possible that with growing international market integration the substitutability between goods from different origins increases. Hence, differences in the results might also stem from differences in the underlying time horizon. Additional explanations for diverging results have been mentioned in the literature review in section 2.

6 Conclusion and outlook

In this paper we estimate sector-specific Armington elasticities for a dataset of 9 European countries. We obtain results for both single 2-digit-level sectors as well as pooled sectors. In both single-sector and pooled estimations we find substantial differences both across sectors and across countries. Only some of our coefficients are comparable in magnitude to the estimates for the US which are often used as a reference in CGE model specification. Our results differ as well from the existing estimations for other countries outside the US even though the magnitude and variance of our results is comparable in general. It becomes clear from comparing our results across the included countries that country-specific preferences exist and should not be ignored even for a rather homogenous group of countries like the EU.

Our results support the view that a non-negligible uncertainty about the magnitude of Armington elasticities prevails and that both more investigation of these and a more sensitive modeling practice are needed. The significant cross-country differences emerging from our results as well as from the comparison with other countries clearly show that it is not acceptable to use estimated elasticities for another country when specifying a CGE model - which is very often done in practical CGE work. One might well end up with biased results from CGE simulations due to a misspecification of the elasticities.

We conclude that much more effort should be spent in both collecting and providing the required data and estimating the elasticities for each country and sector to be included in applied models separately. As the reliable estimation of elasticities of substitution, however, implies rather strong data requirements and, if done soundly, requires quite some effort, it would be ideal if data and results from specific countries would be made available to other modellers in order to improve the general quality of CGE model results in general.

If estimated elasticities are not available and cannot be obtained, modellers should handle this problem transparently and try to address this known bias in their model results by providing a detailed sensitivity analysis with respect to the choice of the elasticity set. An increased effort in both aspects, the estimation of elasticities and a transparent sensitivity analysis would increase the reliability of CGE model results as well as the reputation of the modelling approach as a whole.

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7 Appendix

Table A.8: Stationarity and integration tests for ISIC Rev. 3

ISIC Rev. 3 Sector		CZE			DNK			GRE		
		$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid
13	Mining of metal ores	-	-	-	-	-	-	l(1)	?	l(1)
14	Other mining and quarrying	-	-	-	-	-	-	l(1)	l(1)	l(1)
15	Food products and beverages	l(2)	l(2)	l(2)	l(2)	l(1)	l(2)	l(1)	l(1)	l(0)
16	Tobacco products	-	-	-	l(1)	l(1)	l(0)	-	-	-
17	Textiles	NI	l(2)	l(1)	l(1)	l(0)	l(0)	l(1)	l(1)	l(1)
18	Wearing apparel	l(2)	l(2)	NI	l(1)	?	l(1)	l(1)	l(2)	l(0)
19	Leather and related products	l(1)	NI	l(1)	-	-	-	(1)	l(0)	l(1)
20	Wood and cork products	l(0)	l(1)	l(0)	l(1)	l(1)	l(0)	l(1)	l(1)	l(1)
21	Paper and paper products	l(2)	l(2)	l(1)	l(1)	l(0)	?	l(1)	l(0)	l(0)
22	Publishing, printing and reproduction of recorded media	l(1)	l(1)	l(1)	l(2)	l(2)	l(0)	l(2)	l(1)	l(0)
23	Coke, refined petroleum products and nuclear fuel	l(2)	NI	l(0)	-	-	-	-	-	-
24	Chemicals and chemical products	l(1)	NI	l(1)	l(1)	l(1)	l(0)	?	l(1)	l(2)
25	Rubber and plastics products	l(1)	l(2)	l(0)	l(1)	l(1)	l(1)	l(1)	l(1)	l(0)
26	Other non-metallic mineral products	NI	NI	l(1)	l(1)	l(1)	l(0)?	l(1)	l(0)	?
27	Basic metals	l(2)	l(0)	l(1)	l(1)	l(2)	l(1)	l(0)	l(0)	l(0)
28	Fabricated metal products	-	-	-	l(1)	l(1)	l(1)	-	-	-
29	Machinery and equipment	l(2)	l(2)	l(1)	l(1)	l(1)	l(1)	l(1)	l(1)	l(0)
30	Office, accounting and computing equipment	NI	l(1)	NI	l(1)	l(1)	l(1)	-	-	-
31	Electrical machinery and apparatus	l(0)	l(1)	l(1)	l(2)	l(2)	l(1)	l(0)	l(1)	l(1)
32	Radio, television and communication equipment	NI	l(1)	l(1)	NI	l(0)	?	l(1)	l(1)	l(2)
33	Medical, precision and optical instruments	l(0)	l(1)	l(1)	l(1)	l(2)	?	l(1)	l(1)	l(1)
34	Motor vehicles, trailers and semi-trailers	l(2)	l(2)	l(0)	-	-	-	-	-	-
35	Other transport equipment	NI	l(2)	NI	l(1)	?	l(0)	-	-	-
36	Furniture, other manufacturing	l(2)	l(1)	l(2)	l(1)	l(0)	l(1)	l(0)	l(0)	?

Table A.9: Stationarity and integration tests for ISIC Rev. 4

	ISIC Rev. 4	FIN			FRA			ITA			HUN			AUT		
	Sector	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid	$\frac{imp}{ds}$	$\frac{dsdef}{impdef}$	resid
9	Mining support service activities	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	-	-	-	-	-	-	I(0)/I(1)	I(1)	I(0)
10	Food products	I(0)/I(1)	I(1)	I(0)	I(1)	I(1)	I(2)	-	-	-	-	-	-	I(1)	I(2)	I(0)
11	Beverages	I(0)/I(1)	I(2)?	I(0)	I(2)	I(1)	I(2)	-	-	-	-	-	-	I(0)/I(1)	I(0)/I(1)	I(0)
12	Tobacco products	-	-	-	I(1)?	I(1)	I(2)	-	-	-	-	-	-	I(1)	I(0)	I(2)
13	Textiles	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	-	-	-	-	-	-	I(1)	I(1)	I(2)
14	Wearing apparel	I(1)	I(1)	I(0)?	NI	NI	NI	-	-	-	-	-	-	-	-	-
15	Leather and related products	I(0)	I(1)	I(1)	I(1)	NI	I(1)	-	-	-	-	-	-	-	-	-
16	Wood and cork products	I(1)	I(1)	I(0)	I(1)	I(1)	I(0)/I(1)	I(1)	I(0)	I(1)	NI	NI	I(1)	I(1)	I(1)	I(1)
17	Paper and paper products	I(1)	I(1)	I(0)	I(1)	I(1)	I(0)/I(1)	I(1)	I(1)	I(1)	I(2)	I(0)	I(1)	I(1)	I(1)	I(1)
18	Printing and reproduction of recorded media	-	-	-	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	-	-	-	-	-	-
19	Coke and refined petroleum products	-	-	-	I(1)	I(1)	I(1)	I(1)	I(0)/I(1)	I(1)	-	-	-	I(0)/I(1)	I(0)	I(0)
20	Chemicals and chemical products	I(1)	I(1)	I(0)	I(1)	I(1)	I(1)	I(2)	I(0)	I(1)	I(1)	NI	I(1)	I(1)	I(0)/I(1)	I(1)
21	Basic pharmaceutical products and preparations	-	-	-	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(2)	-	-	-
22	Rubber and plastic products	I(1)	NI	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(2)	I(1)	I(0)	I(0)	I(0)
23	Other non-metallic mineral products	I(1)	I(0)	I(1)	I(0)/I(1)	I(0)	I(0)	I(1)	I(1)	I(0)	I(2)	NI	I(0)	I(1)	I(1)	I(0)
24	Basic metals	I(1)	I(1)	I(1)	I(0)	I(2)	NI	I(0)	I(1)	I(1)	I(1)	I(1)/I(2)	I(1)	I(1)	I(1)	I(1)
25	Fabricated metal products	I(0)	I(0)	I(1)	NI	NI	I(1)	I(0)	I(1)	I(1)	I(0)	I(0)	I(0)	I(0)	I(0)	I(1)
26	Computer, electronic and optical products	I(2)	I(2)	I(0)	-	-	-	I(1)	I(1)	I(0)	I(0)	I(0)	I(0)	I(1)	I(1)	I(1)
27	Electric equipment	-	-	-	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(2)	I(1)/I(2)	I(0)/I(2)	I(1)	I(0)	I(2)
28	Machinery and equipment	I(1)	I(1)	I(1)	-	-	-	I(2)	I(1)	I(2)	I(2)	I(1)	I(2)	I(1)	I(1)	I(1)
29	Motor vehicles, trailers and semi-trailers	-	-	-	I(1)	I(1)	I(0)	-	-	-	I(0)	I(1)	I(1)	I(0)	I(1)	I(0)I(1)
30	Other transport equipment	I(1)	I(0)	I(1)	-	-	-	I(1)	I(1)	I(2)	I(1)	I(1)	I(1)	-	-	-