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Abstract

The purpose of this study is to determine the substitution and price elasticities of different production inputs in numerous sectors in order to reveal how much these elasticities vary between sectors. These elasticities will be also used in practice in a vast CGE model. With 71 sectors studied, our study covers more sectors than previous literature and includes both manufacturing and services sectors. The analysis is based on a vast company level micro database from year 2000 to 2009. We use two alternative translog-cost function specifications for the estimation of the elasticities and apply seemingly unrelated regressions (SUR) with fixed effects on the panel data. In total we estimate 142 SUR regressions. We find that while the elasticities tend to concentrate around the same level in many sectors, there are also significant differences both in the substitution elasticities and in the own-price elasticities of various input factors between different sectors. However, the elasticities are not found to differ significantly between the manufacturing sectors and services sectors in general. Due to the significant variation between sectors, sector specific elasticities are recommended to be used in computable general equilibrium models and in other applied economic models that are sensitive to these types of elasticities.

Key words: elasticity of substitution, price elasticity, micro panel data, translog-cost function, sector specific, CGE models

JEL classification numbers: D24, D33, D58

Tiivistelmä

Tämän tutkimuksen tarkoituksena on estimoida useiden eri tuotannontekijöiden hinta- ja substituutiojoustot eri sektoreilla, jotta voidaan nähdä kuinka paljon kyseiset joustot eroavat sektoreiden välillä. Lisäksi näitä joustoestimaatteja tullaan käyttämään käytännössä laajassa yleisen tasapainon malli VATTAGE:ssa. Tutkimus kattaa 71 eri teollisuus- ja palvelualojen sektoria ja on täten laajin tähän asti tehty tutkimus eri sektorien joustoista. Analyysimme on tehty laajalla yritystason mikrotietokannalla vuosilta 2000–2009. Estimoinnit tehtiin kahdella eri tuotantofunktiomuodolla ja ne estimoitiin SUR regressiometodilla, jossa paneelitietokannasta otettiin huomioon yritystason kiinteät vaikutukset. Yhteensä me estimoimme 142 SUR regressiota. Tuloksiemme perusteella useat joustot ovat hyvin samansuuruisia eri sektoreilla, mutta me löysimme myös merkittäviä eroja sekä useiden tuotannontekijöiden hinta- että substituutiojoustoissa sektoreiden välillä. Systemaattisia eroja joustoissa ei kuitenkaan havaittu yleisesti ottaen teollisuusalojen ja palvelualojen välillä. Näiden merkittävien erojen takia suosittelemme sektorispesifien joustoestimaattien käyttöä kaikissa yleisen tasapainon malleissa sekä muissa laskennallisissa talousmalleissa, jotka ovat herkkiä kyseisten joustojen arvoille.

Asiasanat: substituutiojousto, hintajousto, mikrotason paneelitietokanta, transloginen kustannusfunktio, sektorianalyysi, laskennalliset yleisen tasapainon mallit

JEL-luokittelu: D24, D33, D58

Summary

Computable general equilibrium (CGE) models are typically used for the analysis of different policy changes effects. These types of models usually have a microeconomic foundation and they include different utility and production functions for the estimations. Therefore they require various elasticity estimates as inputs for the calculations. In order to obtain reliable results from these models, it is essential to use up-to-date, reliable elasticity estimates in them.

The purpose of this study is to determine the price elasticities of and elasticities of substitution between various production inputs for a large Finnish CGE model – the VATTAGE model. At the same time, we want to study how much these elasticities vary between the different sectors of the economy. We calculate the elasticities for 71 different sectors, covering both manufacturing and services sectors. Thanks to the large number of sectors under study, we can also analyse the distributions of elasticity estimates.

Most of the literature until now has concentrated only on the estimation of elasticities in different manufacturing sectors and typically the numbers of sectors included in the studies have not been high. We provide therefore a needed addition to the literature. Our study is also the first study, to our knowledge, to analyse production elasticities based on microdata in various services sectors. Typically elasticities have been estimates based on macrodata until now. Already at 1987 Solow argued, however, that the substitution between production factors is a microeconomic phenomenon and should be estimated with micro level data.

The analysis is based on a vast company level micro database from year 2000 to 2009. We use two alternative translog-cost function specifications for the estimation of the elasticities and apply seemingly unrelated regressions (SUR) with fixed effects on the panel data. In total, we base the results on 142 SUR regressions (71 sectors * 2 model specifications). The production factors studied include labour, capital, materials, outside services and various energy inputs.

We find that elasticities tend to concentrate around the same level (numerically) in many sectors. Nevertheless, there are also significant differences both in the substitution elasticities and in the own-price elasticities of various input factors between different sectors. In general, the elasticities are not found to differ significantly between the manufacturing sectors and services sectors. Factor intensities, on the other hand, affect the elasticity estimates significantly. For example, the lowest (i.e. most inelastic) own-price elasticities for labour are found in very labour intensive sectors. In these sectors, also the substitution elasticities of capital to labour were found to be the least elastic. On the contrary, some of the highest own-price elasticities on labour were found in relatively capital intensive sectors.

In general, according to our results it is important to use sector specific elasticity estimates in computable general equilibrium and in other macro models, due to the significant differences in the sector specific elasticities. The use of the same elasticity estimate for each sector could lead to seriously biased modelling results.

Contents

1. Introduction

Computable general equilibrium models (CGE models) are used for the numerical analyses of various political options or changes in economic structures. For example, government's climate policies could act as a key factor in reducing emissions, but in order to analyse the excepted impacts of the policies, ex-ante calculations are required. The CGE models utilise production factors own-price and substitution elasticities in the calculations. Especially new technological innovations, changes in economic structures and globalization may affect these elasticities over time. Further, depending on the number of sectors included in a CGE (or other macro) model, the elasticities of different production factors might vary significantly between sectors. It is therefore important to revise the previous elasticity estimates regularly and to estimate the elasticities at as disaggregated sector levels as possible. The main goals of this study are 1) to get better elasticity estimates for the vast, dynamic VATTAGE CGE model of VATT and 2) to see how much in general the different elasticities differ between various manufacturing and services sectors.

The importance of elasticities in CGE models has induced an increasing volume of studies on the substitution possibilities between capital, labour, energy and materials. Most of the literature until now has concentrated only on the estimation of elasticities in different manufacturing sectors and typically the numbers of sectors included in previous studies have not been high. As an addition to the previous literature, we analyse how much the elasticities differ between sectors and what kind of elasticities are prevalent in the numerous services sectors. We estimate the own-price, cross-price and substitution elasticities of various production inputs in 71 different sectors in Finland. The number of sectors analysed is higher than in any previous study. The 71 sectors include agricultural, manufacturing and services sectors.

Already in 1987 Solow argued that the substitution between inputs is a micro economic phenomenon and therefore should be estimated using micro level data. We employ a vast, company level micro database covering approximately 2.2 million observations from the years 2000-2009 for our analysis. Until now there are only a few studies (e.g. Woodland, 1993, Nguyen and Streitwieser, 1998, and Anberg and Bjoerner, 2007) that have used micro data for the estimation of production elasticities. Two of them use cross sectional data, while we employ panel data similar to Arnberg and Bjoerner (2007). Hence, our study seems like a needed addition to the literature that applies micro data for the estimation of price and substitution elasticities.

We apply the widely used translog-cost function approach for the estimation of the elasticities. Our data does not contain information on the quantity of outputs or intermediate inputs (services and materials) used in the production per company that would be required for the estimation of various other production function forms. Further, calculation of the quantity of capital used in each company e.g. with the perpetual inventory method would be extremely cumbersome (as we have more than 230 000 companies included in the dataset in total). We can also avoid endogeneity problems with the use of the cost share method and exogenous price indexes. We calculate the own-price and substitution elasticities for and between capital, labour, materials, outside services and various forms of energy inputs. The system of equations is estimated with seemingly unrelated regressions (SUR) on our panel data with company specific fixed effects and robust standard errors. In total we estimate 142 SUR regressions (71 sectors * 2 model specifications).

In the next section we review some of the theoretical background on constant-elasticity-of-substitution (CES) functions and on estimating elasticities with translog-cost CES functions. Further, we present some of the previous empirical micro studies and their results. In the third and fourth sections we describe our estimation methodology and data, respectively. Section five presents the results and section six concludes.

2. Estimation of production elasticities

2.1 CES function

Although the elasticity of substitution has many implications on various branches of economic theory, economists had until the early 1960s only chosen simple assumptions on the degree of substitutability between inputs. At that time, there were two main competitors: the Cobb-Douglas approach, where unitary substitution elasticity between production factors is assumed, and the Leontief approach, where no substitution is assumed. The mathematical ease of calculations was one of the main reasons for the development of these production forms. However, a major problem with these production forms is the bias in the estimation results if the assumptions concerning the substitution elasticities appear to be wrong. In 1961, Arrow, Chenery, Minhas and Solow published a paper in which they derived the Constant-Elasticity-of-Substitution (CES) production function.

A large and growing body of literature has investigated constant-elasticity-of-substitution production function. In their pioneer study in 1961, Arrow, Chenery, Minhas and Solow attempted to derive a mathematical function having the properties of homogeneity, constant elasticity of substitution between capital and labour, and the possibility of different elasticities for various industries. They managed to identify one general production function that fulfils these properties with Cobb-Douglas and Leontief functions as special cases. The derived production function was presented in the following form:

(2.1.1) $$V = \gamma(\delta K^{-\rho} + (1-\delta)L^{-\rho})^{-1/\rho}.$$

Where V, K and L are output, capital and labour, respectively. γ is defined as the (neutral) *efficiency parameter*, δ is the *distribution parameter*, and finally, ρ captures a transform of the elasticity of substitution as the *substitution parameter*. Arrow et al (1961) state that this production function was named as constant-elasticity-of-substitution since for all values of K/L it exhibits a constant elasticity of substitution. The actual elasticity of substitution, σ, is in the form:

(2.1.2) $$\sigma = {}^{1}/_{(1+\rho)}.$$

The production function transforms to the Cobb-Douglas production form if the elasticity of substitution is equal to one. The authors highlight a couple of interesting cases considering the curvature of the isoquants: when $0 < \rho < \infty$ the elasticity of substitution is $\sigma < 1$, and if $\rho = -1$ the inputs are perfect substitutes as $\sigma = \infty$. Finally, if $\rho = \infty$, the substitution of elasticity is zero, there is no substitutability between capital and labour and the function turns to the Leontief form. To determine the elasticity of substitution between capital and labour they conducted an empirical study on manufacturing sector data and concluded that it may be usually less than unity (Arrow et al., 1961).

2.2 Previous studies

There exist a large body of literature on measuring elasticity of substitution, but the empirical findings are rather controversial and there is no general agreement about the degree of substitutability between inputs. In fact, already in 1987 Solow argued that the problem with measuring elasticity of substitution between capital and energy is not possible to solve using aggregate data. He concludes that using aggregate data results in biased estimates because they capture more than simply technological substitution. Therefore, Solow suggests that microeconomic data should be used instead. To our knowledge there exist only a few studies using micro data for the estimation the substitution elasticities (including Woodland 1993, Nguyen and Streitwieser 1999, Arnberg and Bjoerner 2007).

The first study on the elasticity of substitution conducted with microdata was done by Woodland in 1993. As he states in the introduction, all the previous published research on industrial energy demand employ aggregated data. Instead, he carried out a micro-level econometric analysis of the industrial demands for coal, oil, gas, electricity and other inputs (capital and labour). He argues that a microdata approach allows for a closer relation with the theoretical models that are, in fact, based on the theory of an individual firm. The data covered an eight-year period, 1977-1985, and consisted of approximately 80,000 observations in total or approximately 10,000 manufacturing establishments' observations per each year. Woodland paid special attention to the patterns of energy demand. He defined nine empirically relevant fuel combinations, which were used in the estimations. The results indicated higher own-price elasticities for fuel products than observed in previous literature based on macrodata. He found e.g. the own-price elasticity of electricity to be in the range of -1.2 to -1.4, and for oil and gas to be around -2.

In 1999, Nguyen and Streitwieser pointed out that there are several issues to improve in estimating the elasticities of substitution. Those were model specifications, functional forms, input measurement and the data used. In the light of dataset, both studies (Nguyen and Streitwieser, 1999, and Arnberg and Bjoerner, 2007) refer to Solow's (1987) argument that factor substitution is a microeconomic phenomenon and it should be investigated using microeconomic data. Luckily, during the past few decades access to micro data has improved significantly, which has meant new opportunities in empirical research. Nguyen and Streitwieser (1999) highlighted in their study Solow's idea that when input prices fluctuate and manufacturing output consists of many different products with different energy intensities, changes in the composition of aggregate output takes place simultaneously with factor substitution that occurs within the production of each product. Thereby, a researcher is not able to isolate these effects with aggregate data. The data they used was cross-sectional plant level dataset with all in all 10,412 plant observations. They made two major findings: in most of the industries, the elasticities of substitution were quite similar across plants of different sizes within an industry, and the used inputs (capital, labour and materials) were highly substitutable. Their research covered 10 manufacturing sectors and some variation was found in the elasticity estimates between those sectors.

Arnberg and Bjoerner (2007) provide also an interesting micro data study on substitution between capital, labour and energy. They employed a micro panel data and, thus, added the time dimension in the estimation. They included data from some 7 major manufacturing sectors in their analysis, but did not report sector specific results at all. As the authors state, the results were contradictory compared to the previous studies. They found that capital and electricity (as well as other energy) are complements with capital instead of substitutes like the previous studies had concluded. In fact, Solow (1987) compared some earlier studies and found that cross-section data has been suggested to yield long-run and time-series data short-run elasticities. Arnberg and Bjoerner also state that it is likely that the previous micro cross-section studies have produced biased estimates. They also argue that using the wage bill divided by the number of employees as the price of labour is more likely to reflect differences in quality of labour across companies than the actual exogenous wage differences. Therefore, the price of labour calculated this way could be endogenous. This endogeneity problem can be reduced or even eliminated with the use of panel data with fixed effects. At company level the composition of high and low quality labour can be assumed to be relatively stable over time. Hence, the use of panel data with fixed effects reduces the endogeneity problem resulting from the use of average salary levels.

Arnberg and Bjoerner conclude that own-price elasticities are quite small, i.e. the factors are inelastic. This result implies that e.g. the use of energy taxes for reducing CO2-emissions can be cumbersome. Due to the complementarity between capital and energy inputs, there would be a need to restrict/tax both of the inputs in order to reduce CO2-emissions. It is the most efficient way to cause factor substitution from energy to other inputs. Some of their own-price elasticities obtained from the translog-cost function are positive, which is not preferable. They mention that translog model may not be the best to describe production possibilities when factor substitution is low and factor shares are small and heterogeneous.

The choice of data has had an enormous influence on estimation results. Detailed meta-analysis on capital-energy substitution studies by Koetse et al (2008) reveal that the type of data and aggregation of variables are significant in defining the magnitude of substitution in empirical studies. Furthermore, they point out that model assumptions concerning returns to scale, technological change and separability of input factors affect the outcomes. They define typical Morishima and cross-price (in which properties we will return later) elasticities for the short, the medium and the long run. The short run elasticities can be obtained using time series data. The Morishima elasticities of capital and energy in the short run were typically found to be around 0.64. For the calculation of medium and long run Morishima elasticities, panel and cross section data are used, respectively. The resulting average elasticity estimates are at 0.89 for medium and 1.21 for long run. The authors conclude that capital-energy substitution is a long run process and is influenced by increases in energy prices. Therefore, e.g. attempts to increase demand for energy saving capital inputs by higher energy taxes will require time.

3. Methodology

3.1 The translog-cost function approach

Previous studies have shed light on the estimation of CES production functions and there exists quite a large number of estimation techniques. Koetse et al (2008) mention that especially nested production functions and flexible functional forms are used for empirical studies on capital-energy substitution. The authors argue that the nested CES-function is too restrictive because the pure substitution between capital and energy cannot be estimated in some specific cases. One popular method has been the use of translog production function, which was identified by Christensen, Jorgenson and Lau in 1973. It belongs to the category of flexible functional forms.

A translog production function is rather easy to estimate and there is no need to pose any extra restrictions on technology, such as constant returns to scale, or on the substitution potential of the input factors. The major problem with estimating the translog function is that the inputs may be endogenous. In this case, ordinary least squares estimates would be biased. On the other hand, the input prices of a translog-cost function mostly do not have problems with endogeneity. Therefore, most of the empirical studies using translog form apply the duality theory of production and costs, and use to the translog-cost function for the estimation. (Koetse et al, 2008) We will do the same.

Greene (2002) introduces the translog-cost function in more detail. Let us assume that the production is described by the following function: $Y = f(x)$. In order to minimize the costs with given input prices and the level of production, we are able to obtain the cost minimizing input factor shares: $x_i = x_i(Y, p)$ for production inputs $i = j = \{1,2, \dots, M\}$. The total costs of production can be described by a cost function:

(3.1.1) $$C = \sum_{i=1}^{M} p_i x_i(Y, p) = C(Y, p)$$

For example, if constant returns to scale are assumed, the average cost function $c(p) = C/Y$. In general, the cost minimizing input demands can be derived by Shephard's lemma (1970). If $C(Y, p)$ gives the minimum production costs, the cost minimizing input demands consist of:

(3.1.2) $$x_i^* = \frac{\partial C(Y,p)}{\partial p_i} = \frac{Y \partial c(p)}{\partial p_i}$$

An alternative solution is to logarithmically differentiate the function in order to obtain cost minimizing input factor shares:

(3.1.3) $s_i = \frac{p_i x_i}{C} = \frac{\partial logC(Y,p_i)}{\partial logp_i}$

For estimation purposes the total cost function can be expanded with second order Taylor series to the point $log\,\mathrm{p} = 0$. Koetse (2006) mentions that the point chosen for approximation does not affect scale and substitution elasticities even though the estimated parameters are affected. Therefore, the approximation point is set to zero where all the derivates can be approximated. If we assume those derivates as coefficients, and impose the symmetry of cross-prices (see equation 3.1.8) in the equation, the cost function is defined as:

(3.1.4) $\log c = \beta_0 + \beta_1 logp_1 + \cdots + \beta_M logp_M + \delta_{11}\left(\frac{1}{2}log^2 p_1\right) + \delta_{12} logp_1 logp_2 + \delta_{22}\left(\frac{1}{2}log^2 p_2\right) + \cdots + \delta_{MM}\left(\frac{1}{2}log^2 p_M\right)$

The function above is the translog-cost function and it reduces to Cobb-Douglas form if all δ_{ij} are zero. In order to estimate the cross-price and substitution elasticities with the translog-cost function approach, we are interested in estimating the cost shares instead of the full cost function. In line with Greene (2002), the cost shares are defined by:

(3.1.5) $s_1 = \frac{\partial logc}{\partial logp_1} = \beta_1 + \delta_{11} logp_1 + \delta_{21} logp_2 + \cdots + \delta_{1M} logp_M,$

$s_2 = \frac{\partial logc}{\partial logp_2} = \beta_2 + \delta_{12} logp_1 + \delta_{22} logp_2 + \cdots + \delta_{2M} logp_M,$

...

$s_M = \frac{\partial logc}{\partial logp_M} = \beta_M + \delta_{1M} logp_1 + \delta_{2M} logp_2 + \cdots + \delta_{MM} logp_M.$

The β_i parameters are identified as symmetry parameters and the coefficient δ_{ij} as Slutsky's elasticities of substitution. Slutsky's elasticities are symmetric by definition and hence we need to make the symmetry restriction in our estimations.

(3.1.6) $\delta_{ij} = \delta_{ji}$

Because the cost shares must sum up to one, in addition to symmetry, we need also restrictions for linear homogeneity:

(3.1.7) $\beta_1 + \beta_2 + \cdots + \beta_M = 1.$

$\sum_{i=1}^{M} \delta_{ij} = 0$

$\sum_{j=1}^{M} \delta_{ij} = 0$

These restrictions are the minimum to describe a well behaving technology of the cost function. The technology is linearly homogenous in input prices. In addition, it has to be positive and monotonically increasing in terms of input prices and output, and the input prices should be concave (Truett and Truett, 2007).

In line with Greene (2002) and Arnberg and Bjorner (2007), the system of share equations (3.1.5) can be estimated using a seemingly unrelated regressions (SUR) model. There is, however, a problem of singularity in the disturbance covariance matrix of the share equations in these types of systems of share equations. A popular approach to impose the restrictions and to solve the problem of singularity is to divide the first M – 1 input prices by the M^{th} input (for instance Arnberg and Bjorner 2007, Truett and Truett 2005, Koetse et al 2008). This eliminates the last term in each row and column of the parameter matrix. The M^{th} input can be freely chosen and the problem of singularity erases as the M^{th} equation is dropped (in fact Greene (2002) suggests to compute maximum likelihood estimates to ensure invariance with respect to the choice of which equation to drop, while Koetse et al (2008) consider the choice arbitrary). For conventionality and the possibility to use symmetry restrictions in estimation, we use also the SUR method with company level fixed effects and robust standard errors to estimate the parameters of the system of share equations (3.1.5).

3.2 Estimation of elasticities with translog-cost function

In the next few paragraphs we demonstrate how five different elasticities can be calculated from the estimated parameters of the translog-cost function.

The Allen elasticity of substitution (AES, or Allen-Uzawa elasticity of substitution identified by Allen (1938) and Uzawa (1962)) can be calculated by function (3.2.1) using the parameters, $\hat{\delta}_{ij}$, estimated from the translog-cost share functions and the cost share s_i and s_j of the input factors in question:

(3.2.1) $$AES_{ij} = (\hat{\delta}_{ij} + s_i s_j)/s_i s_j$$

For our purposes, more interesting forms of elasticity are the cross-price (CPE) and own-price elasticities (PE), which are related to the Allen elasticity of substitution by: $CPE_{ij} = s_j AES_{ij}$. Cross-price elasticity measures the percentage change in demand for factor i due to percentage change in the price of factor j and it is scale free unlike the AES. The elasticity formula of CPE is:

(3.2.2) $$CPE_{ij} = (\hat{\delta}_{ij} + s_i s_j)/s_i$$

A modification of the CPE is the own-price elasticity of an input factor, which can be calculated by (Greene, 2002):

(3.2.3) $PE_i = (\hat{\delta}_{ii} + s_i(s_i - 1))/s_i$

Koetse et al (2008) discuss the properties of the presented elasticities and clarify the distinctions between them. Firstly, AES is symmetric by definition, $AES_{ij} = AES_{ji}$, while CPE is not. Secondly, AES is more sensitive to cost shares than CPE, while CPE is a scale free elasticity measure. The latter is preferable if we want to compare the results with other studies. Moreover, the authors emphasize the non-symmetric nature of the cross-price elasticities. It is not likely that the substitution potential of capital for labour is the same as labour for capital. Therefore they have different adjustment mechanisms for price changes.

To measure the substitution potential between inputs, we employ the Morishima substitution elasticity (MES). It has several advantages compared to AES (for a closer comparison between Allen and Morishima elasticities, we recommend Blackorby and Russel (1978)). Moreover, the micro data study by Nguyen and Streitwieser (1998) also calculated MES, meaning that the use of MES would allow us to compare our results with previous findings. Even though MES is recognized superior to AES by economists, it is still a relatively rarely used measure (Nguyen and Streitwieser, 1999). The Morishima substitution of elasticity was developed by Morishima in 1967 and it measures purely the technical substitution potential between the input factors. The MES is calculated as:

(3.2.4) $MES_{ij} = CPE_{ij} - PE_j$

MES is a one-price-two-factor elasticity and measures the curvature of the production isoquants. In other words, it measures the percentage change in the P_i/P_j ratio when the price of input *j* changes one percent, assuming that the prices of other inputs remain constant. The difference between cross-price elasticity and MES rises from the income effect caused by a price change. CPE consists of two separate effects: the income effect and the substitution effect. Substitution effect measures the change in demand of i when the price of j changes. The income effect instead, measures the change in demand for *i* when income changes because of price change in P_j.

In addition to cross-price and Morishima elasticities, we calculate shadow elasticities of substitution (SES). The reason for this is that we still need substitution elasticities that are symmetric for the VATTAGE-model. Fortunately, also Nguyen and Streitwieser (1999) calculate the SES, so we can still compare our results to theirs. SES is a modified version of MES made to measure the technical substitution between two inputs in response to changes in their relative prices (Chambers, 1988). The SES is presented as:

(3.2.5) $SES_{ij} = \frac{s_i}{s_i+s_j} MES_{ij} + \frac{s_j}{s_i+s_j} MES_{ji}$

The SES is a two-factor-two-price elasticity, calculated as a weighted average of two MES. The weights are given by the relative factor cost shares. Therefore, it has an advantage compared to MES: it measures the responsiveness of input ratios to changes in their relative prices. With SES we are able to achieve measures for substitution elasticities that are symmetric, have a theoretical background, are easy to calculate and, therefore, are highly applicable.

3.3 Estimation methodology and calculation of elasticities

In the VATTAGE CGE model, in which our elasticity estimates will be especially used, it is assumed that intermediate inputs in aggregate are not substitutes for capital, labour and energy inputs. In other words, in the top level of the production input mix a Leontief production function is assumed. Intermediate inputs, primary factors and energy and other costs are assumed to have a substitution elasticity of zero in that CES format. (Honkatukia, 2009) Similar assumption was made e.g. by Arnberg and Bjoerner (2007). Generally, materials are often left out when production elasticities are estimated. Nevertheless, according to Rouvinen (2002) e.g. labour and materials are substitutes in the Finnish manufacturing industry. Consequently, we calculate the translog-cost function with two alternative specifications: One were materials are included as an input factor and one where they are excluded.

In line with Arnberg and Bjorner 2007, we estimate the following system of equations for each 71 sectors individually:

(3.3.1) $$S_{int} = \beta_{in} + \sum_{j=1}^{M-1} \delta_{ij} ln \frac{P_{jnt}}{P_{Mnt}} + \alpha_{Ti}T_t + \alpha_{Ii}I_{nt} + \alpha_{Yi}Y_{nt} + \varepsilon_{int}$$

Where, i and j include: Capital, labour, outside services, various energy forms and materials (in one specification). Indices n and t are for companies and time. Outside services are left as the numeraire (j=M) and are calculated after estimations using the homogeneity and symmetry conditions. T, I and Y refer to time/trend, individual company specific dummies, and logarithm of sales (i.e.income) respectively. Parameters β_{in} are the constants. The use of company and time specific dummies captures the effects of time invariant factors that may influence the companies' use of inputs and transforms the regressions to panel data fixed effect models. The energy inputs are calculated for certain sectors only and we separate them to different inputs. The systems of equations (3.1.1) are estimated with the seemingly unrelated estimations, where Newey-West standard errors are used in order to correct for auto-correlation and heteroscedasticity. The earlier mentioned symmetry restrictions are imposed. Given the two model specifications and 71 sectors, we estimate in total 142 SUR regressions.

For the final calculation of the cross-/own-price, Morishima, and shadow elasticities of substitution, the estimation results, $\hat{\delta}_{ij}$, are used in line with the equations (3.2.2)-(3.2.5). Only estimation results that are significant at 10% level are used, otherwise the coefficients are assumed to be zero. The average cost shares s_i and s_j in each sector are calculated from the company specific observations over the whole ten years period. The cross- and own-price elasticities calculated by equation 3.2.2 and 3.2.3 are used to calculate the Morishima elasticities of substitution with the formula 2.2.4. Finally, the shadow elasticities of substitution, in equation 2.2.5, are calculated using the MES estimates.

The standard errors for price- and Morishima elasticities are calculated by using the standard errors of the coefficients, the covariance matrixes and by applying the Delta method. The estimated standard errors for coefficients were used in the following way to calculate variances and standard errors for cross- and own-price elasticities:

(3.3.2) $$var\left(CPE_{ij}\right) = (-\frac{1}{s_i})^2 * var(\hat{\delta}_{ij}),$$

where s_i is the factor i's cost share and $var(\hat{\delta}_{ij})$ the estimated variance of the delta-coefficients. The same can be applied for own-price elasticities. With the use of cross- and own-price elasticity variances, the variances of the last factor input (outside services)[1] and the variances of the MES can be calculated. The standard errors of MES are calculated by:

(3.3.3) $$var\left(MES_{ij}\right) = var\left(CPE_{ij}\right) + var\left(PE_j\right) - 2 * cov\left(CPE_{ij}\right)\left(PE_j\right)$$

The last term in the equation 3.3.3 is approximated by the covariance of the delta estimates, $cov(\delta_{ij}\delta_{jj})$.

[1] $var(PE_M) = \sum_{i,j=1}^{M-1} cov(\delta_{ij}\delta_{ji})$. For these calculations, the covariance matrix of the SUR estimations are used.

4. Data

The Finnish YRTTI micro database on companies is based on annual tax forms sent to the public authorities and, hence, it is a nearly fully representative collection of companies in Finland. It includes both manufacturing and services sector companies. The database includes data from year 1994 until 2009. However, especially the comparability of the data between the very beginning and end of the observation period is cumbersome due to changes in taxation laws and on companies' reporting requirements. This research will limit to analyse the data from year 2000 until 2009.

The database contains large amounts of data for each company, including e.g. the legal form of the company, their main sector of business, their location, all financial accounts information (total revenue, profit/loss of the accounting period, salary costs, intermediate product costs, depreciations and amortizations, financing costs and various other detailed cost categories) and all balance sheet information (values of different types of capital assets, own capital, debt, etc.). There are around 230,000 companies in the database for each year excluding self-employed[2]. The data was carefully checked for errors and some unreliable observations were dropped[3].

The YRTTI-database is complemented with company level annual energy use statistics from the Finnish Environment Institute (SYKE). This data on energy usage includes the amount of electricity, gas and heat bought (in Gwh) together with the annual use of various fuels (e.g. light and heavy petroleum oil, beat and wood based energy forms), all reported in terajoule. The data was also carefully checked and corrected to match the YRTTI-data. Unfortunately, the energy usage statistics are available only for a selection of companies that belong to the heavy energy user sectors. Therefore the energy inputs' analyses could be conducted only in a few sectors.

In total the data used includes some 2,2 million observations for the years 2000-2009, with one observation including data for one company at a specific year. Since there is natural entry and exit of companies all the time, the final panel is unbalanced. Only companies with at least one employee were included in the sample, since no salary estimates could be obtained for companies that did not report the number of their employees. Similarly, only companies that reported at

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[2] E.g. in year 2008 the database includes 168,374 self-employed, 70,566 companies of other forms than Limited company (mostly SMEs) and 178,274 Limited companies. Limited company refers to a company that is listed in the stock exchange (e.g. German GmbH, Spanish S.A and American Corporation correspond mostly to the legal form).

[3] In total, some 8000 unreliable seeming observations were dropped from the total of 2.2. million observations.

least some costs at a given year were included in the estimation sample (in order to have all cost shares together sum to one). The companies were aggregated to 82 main sectors used in the VATTAGE model based on their 5-digit sector codes (which follow approximately the NACE classification). For some sectors very low numbers of observations were available. This dropped the number of sectors to study to 71. The 71 sectors used in the analysis cover still all major sectors of the economy, including agricultural production, manufacturing and services sectors (see Annex 1 for the full list).

Since we have data on employees and labour-costs at firm-level, the price for labour is calculated as a simple average labour cost per employee in each firm. Therefore the labour prices are very heterogeneous. For the price of capital we need a proxy. We combine a variety of different capital assets in the cost of capital (such as buildings, machinery, land and financial assets), which have different life-spans and prices. Most of a typical firms' yearly investment decisions can be expected to pay themselves in a relatively short period of time and be financed by foreign capital. Therefore, the price for capital is assumed to follow the 12-month euribor index, which is taken from the website of Bank of Finland. Price of materials is the producer price index per sector. The price for outside services is, again, the producer price index for services. It describes the price development in business services provided to companies and to the public sector. The indexes are taken from Statistics Finland. Similarly, data from the Statistics Finland on the prices of the various energy forms are used as indicators of the price of the various energy inputs. All of the price indexes are assumed to be exogenous for a single company. Further, similar to Arnberg and Bjoerner (2007), we assume that the use of company level fixed effects in our panel data corrects most of the possible endogeneity bias in the salaries (between companies). Based on the findings of Solow (1987), we obtain short- to medium term elasticity estimates with the use of panel data with yearly variations in cost shares and in prices.

5. Main results

5.1 Own-price elasticities

Figure 1 shows 1) how price sensitive the different inputs are in the short- to medium term and 2) how much variation there is between sectors in the own-price elasticities of different production inputs. In other words, figure 1 presents the frequency of different own-price elasticities' levels obtained for the various input factors in the 71 sectors studied. No sector level weights are used in the formulation of the frequencies. The elasticity estimates of labour, capital, outside services, electricity and other energy forms reported in figure 1 are based on the model specification where materials are excluded. The own-price estimates for materials are, again, obtained from the model where materials are included.

Labour seems to be the least price elastic input with own-price elasticities calculated to be between -0.3 and 0 in all the studied sectors. Changes in the price of labour have then only a small, or zero, impact on labour demand. Labour's own-price elasticities vary also the least of all input factors' own-price elasticities. As the labour estimates are based on the salaries per employee, they relate to the external demand elasticity of labour (in comparison to internal labour elasticities, which relate to number of hours worked). The estimates obtained match well previous findings on the Finnish external labour demand elasticities (Honkapohja et al, 1999) and estimates from various other countries (Chetty et al, 2011).

Similarly, capital is found to have relatively inelastic own-price elasticities. They vary from -0.9 to 0 in the sectors studies, but are mostly around -0.4 to -0.3. Outside services and materials are, to the contrary, the most price sensitive inputs together with the various energy inputs. The own-price elasticities of the outside services vary between 0 and -0.9 and for materials between -0.15 and -2.5. Due to the low numbers of observations in the energy usage records, in comparison to the observations (in the main company database), for most of the energy inputs the regression results were not significantly different from zero. Hence, the own-price elasticities are simply calculated with the cost shares and are estimated to be around -1. Annex 2 includes the sector specific results.

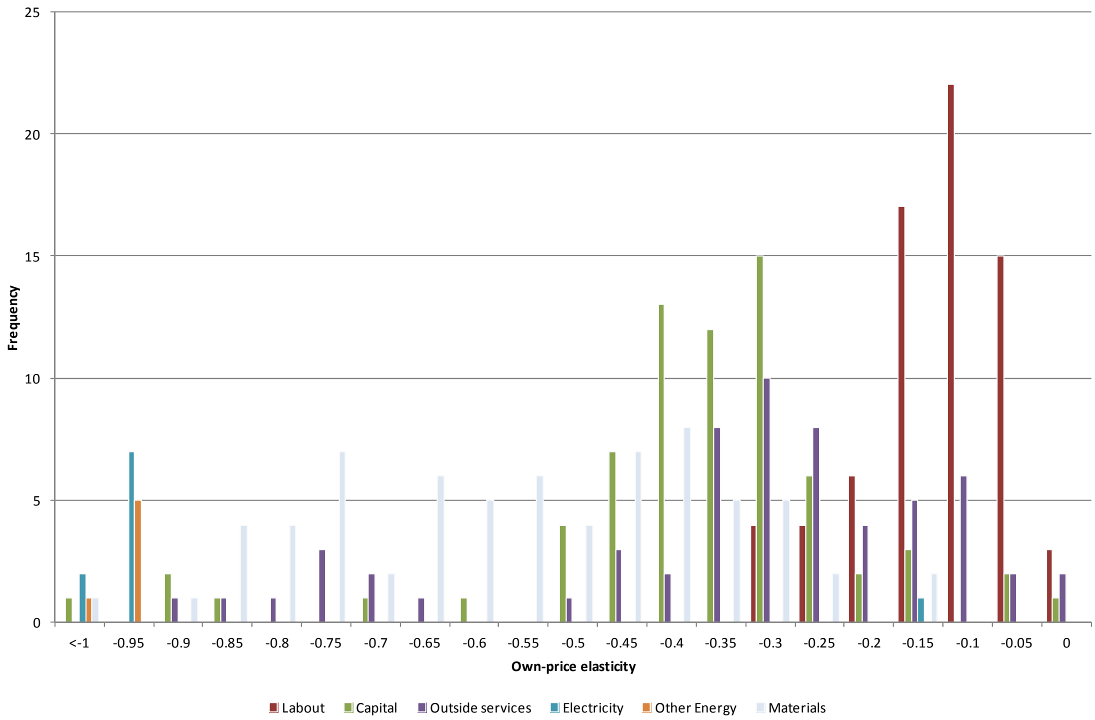
Our own-price elasticities for labour and capital are very close to the results of Arnberg and Bjoerner (2007). Their results on the own-price elasticity of labour and capital, also calculated by a translog fixed-effects model, were -0.08 and -0.45, respectively. Our sector level elasticities are mostly around -0.1 and -0.35 for labour and capital, correspondingly. Similarly, Woodland (1993) found reasonably low own-price elasticities for labour and capital (averages of -0.3 and -0.4 for nine different input combination models). Woodland and Nguyen et al (1998) own-price elasticities for electricity were over unity in absolute value (-

1.3 and -3.8). Arnberg and Bjoerner, however, found significantly lower elasticities of -0.21 for electricity. Our results lie somewhere between these previous studies, but since the majority of the estimates for electricity are not based on significant estimations results, we have some doubts on their validity. As pointed by Arnberg and Bjoerner (2007), the difficulties on estimating the energy factors elasticities result especially from the fact that their factor cost shares are relatively low and heterogeneous. Also the relatively low numbers of observations compared to the observations on other factor inputs increase the difficulty in obtaining significant estimates.

The elasticity estimates that are relatively far from each other are statistically significantly different from each other, based on Welch's t-tests p-values[4]. However, no significant differences are found in the own-price elasticity estimates between all the manufacturing sectors and all services sectors in general. The lowest (i.e. implying inelasticity) own-price elasticities for labour are found in the repair of household goods, repair of motor vehicles and restaurants sectors (all bigger or close to -0.05). Since labour is practically the only production factor in these sectors, the results are rather intuitive. On the contrary, the relatively capital intensive sectors of air transportation, distribution of electricity and manufacture of iron and steel showed the highest labour price elasticities (smaller than -0.3). With regards to the own-price elasticity of capital, the lowest elasticities are found in the manufacture of paper and paperboard, manufacture of jewellery and music instruments and environmental services sectors (elasticities close of -0.1). The highest elasticities are at manufacture of office and electrical equipment, public services and activities auxiliary to insurance services sectors (see Annex 2 for detailed results per sector).

[4] The Welch's t-test are used with two-tails. The H_0 is that the elasticities are the same. If the obtained p-value is lower than 0.05, it is concluded that the elasticity estimates are significantly different.

Figure 1. Own-price elasticities

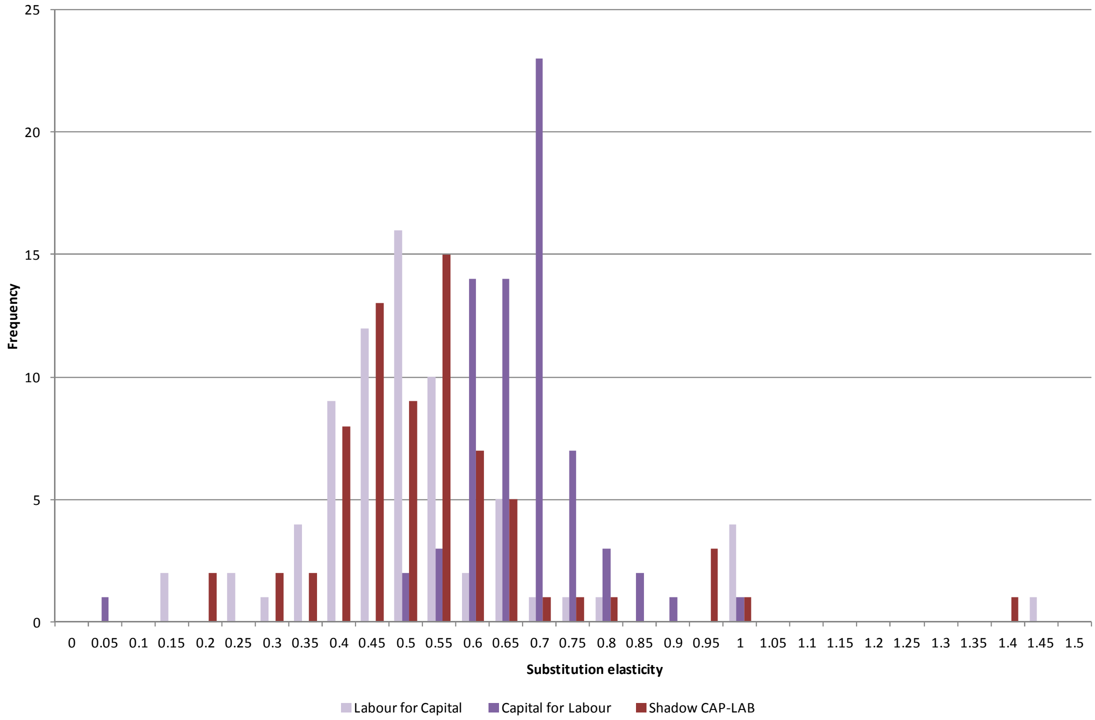


Note: Electricity elasticities could be calculated only for 10 sectors and elasticities of other energy forms in 6 sectors due to data shortages in the energy data.

5.2 Substitution elasticities

Similarly to figure 1, figure 2 presents the frequencies of the different MES substitution estimates obtained for the 71 sectors on the capital-labour substitution. The figure includes the (MES) elasticity of substitution of capital for labour, of labour for capital and the combined shadow elasticity of substitution (SES) between these two input factors. All of these estimates are based on the model where materials are not included in the specification. Similar to Pohjola et al (2005), the aggregate (shadow) elasticity between these two inputs are found to be around 0.5-0.55. There is, however, significant variation in the results between the different sectors based on the Welch's t-tests p-values. Further, also in line with previous literature, it seems that capital can be more easily used as a substitute for labour than the other way round. Similar results were found by Arnberg and Bjoerner (2007) and Woodland (1993) according to cross-price elasticities. They did not report Morishima elasticities. Nguyen et al. (1999) instead reported MES and SES between capital and labour, but their result on the Morishima elasticity of capital for labour was at 1.6 and of labour for capital at 1.1. We find much lower estimates (below unity), but similarly, capital is more substitutable for labour than labour for capital.

Figure 2. Substitution elasticities between labour and capital



Both the SES and MES estimates for the various input factors are found to be significantly different between different sectors. The sector specific results are presented in Annex 2. No persistent differences are found in the estimates between the services sectors and the manufacturing sectors in general. However, for example the MES of labour to capital is found to be slightly higher in the manufacturing sectors in average than in the services sectors. With regards to the MES of capital to labour exactly the opposite applies. These findings correspond to expectations. The lowest MES capital for labour estimates are obtained in sectors where the own-price elasticities of labour are the highest (i.e. most inelastic). As mentioned before, these sectors include especially labour intensive sectors. Similarly, sector level MES of labour to capital estimates correlate heavily with the own-price elasticity estimates of capital. In general, factor intensities affect the elasticities between sectors heavily.

Table 1 provides the average SES estimates between various input factors, which are obtained by function (3.2.5) from the sector specific MES estimates. As explained in section 3.3, table 1 presents the average results 1) from the model specification where materials are not included and 2) from the specification where they are included. The standard errors reported in this table present the variation in the estimates between the 71 sectors. The capital-labour SES varies the least between different sectors, while capital–materials SES and labour–outside services SES vary the most. As there are only few sectors where the energy elasticities could be calculated, the general differences in those elasticities between sectors cannot be defined properly.

The SES estimates of capital–labour and capital–labour–energy nesting are relatively similar no matter which model specification is used. The other elasticities seem more sensitive to the model specification. The differences in the aggregate SES estimates for energy inputs seem to stem from the lower costs share values in the second model specification (and various insignificant estimation results). The outside services estimates, again, are calculated from the other estimates since they are used as the denominator factor in the specification (see section 3). Therefore, they are heavily affected by the estimation results of all other input factors. The own-price elasticity estimates for the outside services include also some positive results and significant differences between the two model specification. However, in all sectors the substitution elasticities between outside services and labour are found to be significantly different from zero and in fact relatively elastic in various sectors. While in a few sectors these two factors are found to be complements, in most of the sectors they are substitutes. This means that in aggregate labour related parts of the production processes seem to be outsourced/bought from external providers in case there are large price differences between using own labour for the task vs. buying the service from some other company.

Similarly, from the SES estimates on the aggregate substitution elasticities between labour vs. materials and capital vs. materials, reveal in line with the findings of Rouvinen (2002) that materials do not have a substitution elasticity of zero with regards to other production inputs. Nevertheless, it should be noted that the (MES) substitution elasticities of materials for capital/labour are significantly higher than the MES of capital/labour to materials[5]. Especially the recent increases in outsourcing and offshoring of production processes could be considered to affect the results.

[5] In average the MES of materials to labour is around 0.9, materials to capital around 1.1, while MES of labour to materials is around 0.6 and capital to materials around 0.5.

Table 1. Average SES substitution elasticities, different model specifications

	Model Specification	
Substitution elasticity	Capital-Labour-Energy-Outside services	Capital-Labour-Energy-Outside services-Materials
Capital-Labour (SES)	0.52	0.56
(s.e, between sectors)	(0.18)	(0.19)
Capital-Labour-Energy (SES)	0.56[1]	0.64[1]
(s.e)	(0.26)	(0.19)
All energy (SES)	1.80[2]	1.04[2]
(s.e)	(2.10)	(0.07)
Labour-Outside services (SES)	0.39	0.81
(s.e)	(0.29)	(0.37)
Labour-Materials (SES)	n.a	0.78
(s.e)	n.a	(0.14)
Capital-Materials (SES)	n.a	0.89
(s.e)	n.a	(0.35)

[1] Based on observations from 10 sectors.
[2] Based only on observations from 6 (manufacturing) sector for which energy usage statistics covered more than one energy form. However, it should be noticed that most of the estimations were not significant and hence the substitution elasticities are close to 1.

5.3 Applicability of the results to CGE modelling

Based on the results, it seems important to use sector specific elasticity estimates in any (CGE) modelling exercise. The use of the same elasticity estimates at each sector could lead to biased results. In the VATTAGE model, as an example, the change in the demand for labour is affected by the substitution elasticities and price of other factors inputs (when technological factors are not taken in to account) according to:

(5.1.1) $$\widehat{x_L} = -\sigma_{C,L} * (\widehat{p_L} - \widehat{p_{CL}}),$$

where $\widehat{x_L}$ reflects the percentage change in the demand of labour, $\sigma_{C,L}$ is the composite (SES) substitution elasticity between capital and labour, $\widehat{p_L}$ the percentage change in the price of labour and $\widehat{p_{CL}}$ the percentage change in average of both labour and capital. So, as an example, if a high substitution elasticity (e.g. average 0.5) is used for a very labour intensive sector where the substitution between labour and capital is actually relatively low (say around 0.2), the model will overestimate the effect of any price changes on the demand of labour. Therefore the use of up-to-date, sector specific elasticities is essential for the robustness of CGE models.

While dropping materials from the CES nesting in any CGE model could also result in biased modelling results, most of the CGE models can take still in to consideration the price effect of materials on the demand of other input factors. If e.g. an increase in the price of materials will be significant enough to increase also the full price of the final output, demand of the output will drop. This can again affect the demand of the other input factors negatively. Further, from the company data available it cannot be disaggregated what material inputs each of the companies is buying exactly and how the demand of each input commodity is affected by price changes. CGE models use, on the contrary, input-output matrixes in the calculations, where each industry is consuming various input commodities supplied by other industries. In the VATTAGE model each industry is able to consume around 900 commodities produced by other companies at the most disaggregated level. Hence, while the results of this study show that in aggregate there is substitution between labour, capital and materials, the results from the model specification where materials are left out (i.e. model 1) are used in the VATTAGE model.

6. Conclusions

In this study, we estimate the own-price, cross-price and (Morishima and shadow) substitution elasticities of various factor inputs in 71 sectors based on Finnish company level panel data from 2000-2009. The elasticities can be considered to represent short- to medium term elasticities. One of the main motivations for the study was to obtain up-to-date and sector specific elasticity estimates for the vast computable general equilibrium model of VATT (i.e. the VATTAGE-model). At the same time we obtain also interesting results on the differences of the elasticity estimates between sectors. Further, our study is a needed addition to the literature on estimation of elasticities based on microdata. We cover significantly more sectors than any previous study and include also services sectors analyses.

The estimations are based on a translog-cost function, where the different cost share equations are solved simultaneously with SUR method. Company level fixed effects and time trends are included to account for company specific heterogeneity in the cost shares. The factors studied include labour, capital, outside services, electricity, various other energy forms and materials. Two different model specifications were used: one where all other factor inputs are included except materials and another where materials are also included. In total we perform 142 SUR regressions (71 sectors * 2 model specifications). Contrary to previous studies on factor inputs elasticities made with company level data, our data covers all main sectors of the economy: agriculture, manufacturing and services (and not only manufacturing like in most of the previous studies). 44 of the sectors studied are services sectors. Further, micro and small companies (with less than 50 employees) are included in the database that covers in practise all Finnish companies. In total, the database has around 2.2 million company-year observations.

Based on our estimates, which match well the previous findings, there are significant differences in the elasticity estimates between different sectors. Labour seems to be the least price elastic input and its elasticities also vary the least between sectors. The labour own-price elasticities are calculated to be around -0.3 to 0 in all the studied sectors. As the labour estimates are based on data on average salary per employee, they relate to the external demand elasticity of labour. Similarly, capital is found to have relatively inelastic own-price elasticities. They vary from -0.9 to 0 in all the sectors studies, while are mostly around -0.4 and -0.3. The own-price elasticities of outside services and materials are the most dispersed across sectors. The outside services estimates vary between 0 and -0.9 and for materials between -0.15 and -2.5. Based on Welcht's t-test results the differences in the elasticity estimates are significant.

Similar to Pohjola et al (2005), the aggregate (shadow) substitution elasticity between labour and capital is found to be in average around 0.5-0.55, but the estimates vary from 0.19 to 1.35 across sectors. These differences are also found to be significant. In line with previous literature, it is found that capital can be used easier as a substitute for labour than other way round. According to the estimation results from the model specification where materials are included in the CES nesting, materials have relatively high substitution elasticities with regards to capital and labour. This relates to the increased outsourcing and offshoring of production processes during the 21st century.

In most elasticity types significant differences are found between sectors. However, no major differences are found in the average own-price elasticities or substitution elasticities between the manufacturing sectors and services sectors in general. Factor intensities do, on the contrary, affect the elasticity estimates significantly. For example, the lowest (i.e. most inelastic) own-price elasticities for labour are found in very labour intensive sectors. In these sectors, also the substitution elasticities of capital to labour are found to be the least elastic. To the contrary, the relatively capital intensive sectors show the highest own-price elasticities on labour (smaller than -0.3). In general, according to our results it is important to use sector specific elasticity estimates in computable general equilibrium and other macro models, due to the significant differences in the sector specific elasticities. The use of the same elasticity estimates at each sector could lead to biased modelling results.

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Annex I

List of aggregated sectors in the data

Identification number	Industry
1	Agricultural production
2	Forestry, logging and related service activities
5	Fishing, fish farming and related service activities
103	Extraction and agglomeration of peat
134	Mining of non-ferrous metals
156	Manufacture of food products, beverages and tobacco
179	Manufacture of textiles, wearing apparel and shoes
20	Manufacture of wood and wood products
22	Publishing and printing
212	Manufacture of articles of paper and paperboard
21121	Manufacture of pulp, paper and paperboard
24	Manufacture of chemicals
25	Manufacture of rubber and plastic products
26	Manufacture of glass and ceramic products
271	Manufacture of iron and steel
2725	Manufacture of processed iron and steel products
28	Manufacture of metal products
29	Manufacture of machinery
301	Manufacture of office and electrical equipment
32	Manufacture of electronic and electrical products
33	Manufacture of medical, testing and optical equipment
345	Manufacture of cars and other transport equipment
361	Manufacture of furniture
3626	Manufacture of jewellery, music instruments and toys
37	Recycling of metal and non-metal waste
4013	Production and distribution of electricity, gas and water
41	Collection, purification and distribution of water
4501	Construction of buildings
4502	Civil engineering
4509	Construction service activities
501	Sale of motor vehicles
502	Maintenance and repair of motor vehicles
51	Wholesale trade and commission trade
521	Retail sale
527	Repair of household goods
551	Hotels
553	Restaurants
6023	Road transportation services
61	Water transport

Identification number	Industry
62	Air transport
63019	Road, track and air transport service activities
633	Other transport and travel services
641	Post and courier activities
642	Telecommunications
65	Financial services
66	Insurance services
671	Activities auxiliary to financial intermediation
672	Activities auxiliary to insurance services
7012	Real estate activities
7031	Real estate agencies
7032	Management of real estate
71	Renting of machinery and equipment
72	Computer and related services
73	Research and development
741	Legal, accounting, book-keeping and auditing services; tax consultancy; market research and public opinion polling; business services
742	Architectural and engineering activities and related technical consultancy; Technical testing and analysis
743	Technical testing and analysis services
744	Advertising services
745	Job agencies and personnel recruitment
746	Security services
747	Cleaning services
748	Other business services
7512	Public services
753	Employment, pension and social security activities
80	Education
851	Human health services
852	Veterinary services
853	Social work services
90	Environmental services
9214	Entertainment and news services
9267	Sports and other recreational services
935	Other service activities n.e.c.

Annex II

Table AII.1 Own-price elasticities by sector

		Labour		Capital		Outside services		Electricity		Other energy		Materials	
IND	**Nro of obs**	**Elast.**	**S.e.**	**Elast.**	**S.e.**	**Elast.**	**S.e.**	**Elast.**	**S.e.**	**Elast. (mean)**	**S.e.**	**Elast.**	**S.e.**
1	20886	-0.11	0.12	-0.27	0.54	0.29	0.04					-0.32*	0.04
2	13228	-0.13	0.13	-0.25	0.56	0.08	0.04					-0.93	0.15
5	2731	-0.09	0.00	-0.20	0.13	0.15	0.11					-0.33*	0.12
20	15796	-0.11	0.00	-0.25	0.04	-0.16	0.03					-0.39*	0.05
22	22629	-0.18	0.00	-0.25	0.04	-0.32	0.02					-0.59*	0.11
24	2457	-0.14	0.01	-0.29	0.08	0.12	0.34	-0.98*	0.39	-0.98*	1.08	-0.42*	0.22
25	4652	-0.12	0.00	-0.28	0.05	-0.90	0.05	-1.00*	0.74			-0.66	0.13
26	5071	-0.14	0.00	-0.30	0.06	-0.76	0.20	-1.30*	0.48	-0.95	1.68	-0.46*	0.46
28	28453	-0.11	0.00	-0.35	0.02	-0.88	0.02	-1.00*	0.52			-0.54*	0.05
29	20025	-0.12	0.00	-0.25	0.04	-0.18	0.02					-0.48*	0.05
32	3189	-0.11	0.00	-0.44	0.07	-0.17	0.08					-0.49*	0.14
33	7005	-0.10	0.00	-0.52	0.05	-0.22	0.06					-0.52*	0.09
37	423	-0.15	0.01	-0.89*	0.22	-0.29*	0.19					-0.43*	0.52
41	6610	-0.21	0.01	-0.37	0.08	-0.11	0.10					-0.52*	0.17
51	117084	-0.10	0.00	-0.36	0.02	-0.18	0.01					-0.34*	0.02
61	2470	-0.17	0.01	-0.18	0.11	-0.26	0.08					-0.64*	0.39
62	464	-0.34	0.01	-0.35	0.14	-0.41	0.14					-0.60*	0.72
65	10099	-0.16	0.00	-0.39	0.06	-0.16	0.08					-0.70	0.10
66	319	-0.20	0.01	-0.23	0.25	-0.13	0.27					-0.61*	0.95
71	8139	-0.15	0.00	-0.28	0.06	-0.11	0.06					-1.00	0.14
72	38996	-0.09	0.00	-0.49	0.03	-0.27	0.03					-0.72*	0.12
73	2282	-0.19	0.00	-0.50	0.09	-0.67	0.07					-0.82*	0.64
80	9866	-0.11	0.00	-0.41	0.05	-0.35	0.04					-0.80*	0.23
90	3852	-0.17	0.01	-0.16	0.08	-0.79	0.04	-1.00*	1.35			-0.64*	0.29
103	2060	-0.21	0.01	-0.19	0.13	-0.19	0.04					-0.65*	0.45
134	2792	-0.21	0.01	-0.49	0.12	-0.31	0.04					-0.53*	0.30
156	10949	-0.08	0.00	-0.34	0.04	-0.91	0.04	-0.20	0.32			-0.40*	0.05
179	10731	-0.08	0.00	-0.23	0.06	-0.12	0.04					-0.30	0.06
212	1003	-0.07	0.01	-0.08	0.13	0.29	0.10					-0.41*	0.13
271	292	-0.27	0.02	-0.45	0.24	-0.36	1.62	-0.98*	1.06	-1.00*	1.94	-0.50*	2.49
301	2984	-0.08	0.00	-1.37	0.16	-0.83	0.08					-0.42*	0.11
345	5430	-0.11	0.00	-0.28	0.07	-0.20	0.04					-0.47*	0.13
361	7188	-0.08	0.00	-0.38	0.06	-0.05	0.05					-0.38*	0.06
501	11389	-0.12	0.00	-0.41	0.05	-0.20	0.04					-0.34	0.04
502	42078	-0.04	0.00	-0.37	0.02	0.28	0.04					-0.19	0.02
521	117993	-0.07	0.00	-0.35	0.02	-0.07	0.02					-0.20	0.01
527	4720	-0.02	0.00	-0.45	0.08	0.73	0.14					-0.26	0.06
551	10909	-0.11	0.00	-0.31	0.05	-0.13	0.06					-0.76	0.12
553	42968	-0.06	0.00	-0.41	0.02	0.23	0.04					-0.45	0.02
633	7348	-0.16	0.00	-0.47	0.07	-0.40	0.05					-0.49*	0.18
641	1400	-0.19	0.01	-0.45	0.15	-0.38	0.06					-0.79*	0.78
642	2995	-0.22	0.01	-0.29	0.10	-0.32	0.05					-0.66*	0.44
671	14235	-0.14	0.00	-0.31	0.06	-0.09	0.06					-0.56	0.07
672	1777	-0.10	0.00	-0.92*	0.14	-0.77*	0.12					-0.87*	1.10
741	67561	-0.09	0.00	-0.42	0.02	-0.28	0.02					-2.51	0.15
742	41215	-0.10	0.00	-0.38	0.02	-0.23	0.02					-0.41	0.10
743	2422	-0.12	0.00	-0.34	0.09	-0.32	0.08					-0.77*	0.46
744	15134	-0.14	0.00	-0.44	0.04	-0.37	0.02					-0.65*	0.14
745	4920	-0.10	0.00	-0.73	0.07	-0.72	0.09					-0.78*	0.29
746	2124	-0.09	0.00	-0.44	0.12	-0.17	0.08					-0.80*	0.55
747	9089	-0.11	0.00	-0.46	0.06	-0.30	0.04					-0.85*	0.28
748	21249	-0.14	0.00	-0.47	0.04	-0.33	0.02					-0.43	0.11
851	30343	-0.12	0.00	-0.43	0.03	-0.33	0.03					-0.82*	0.18
852	1344	-0.09	0.00	-0.48	0.15	-0.11	0.09					-0.88	0.17
853	11011	-0.06	0.00	-0.61	0.03	0.29	0.11					-0.81*	0.12
935	12624	-0.05	0.00	-0.37	0.05	0.12	0.06					-0.31	0.06
2725	830	-0.15	0.01	-0.18	0.15	-0.19	0.29	-1.29*	0.61	-1.00*	1.24	-0.58*	1.40
3626	3286	-0.08	0.00	-0.09	0.10	0.19	0.07					-0.85	0.13
4013	3033	-0.33	0.01	-0.32	0.07	0.24	1.04	-0.99*	0.84	-0.82*	0.41	-0.38	0.42
4501	20010	-0.19	0.00	-0.41	0.03	-0.21	0.02					-0.60*	0.10
4502	77013	-0.16	0.00	-0.37	0.02	-0.33	0.01					-0.59*	0.05

IND	Nro of obs	Labour Elast.	S.e.	Capital Elast.	S.e.	Outside services Elast.	S.e.	Electricity Elast.	S.e.	Other energy Elast. (mean)	S.e.	Materials Elast.	S.e.
4509	58953	-0.11	0.00	-0.48	0.02	-0.27	0.01					-0.42	0.03
6023	66697	-0.10	0.00	-0.47	0.02	0.05	0.02					-1.99	0.05
7012	11110	-0.19	0.00	-0.35	0.03	-0.12	0.06					-0.79	0.12
7031	8694	-0.08	0.00	-0.33	0.05	-0.06	0.05					-0.69*	0.17
7032	16846	-0.09	0.00	-0.37	0.04	-0.11	0.03					-0.43	0.17
7512	211	-0.19	0.02	-0.94*	0.52	-0.71*	0.15					-0.76*	1.78
9214	9688	-0.17	0.00	-0.44	0.06	-0.40	0.03					-0.66*	0.17
9267	10555	-0.14	0.00	-0.46	0.04	-0.13	0.04					-0.56*	0.12
21121	620	-0.24	0.01	-0.33	0.14	0.11	0.21	-0.97	0.35	-0.83*	0.80	-0.45*	0.90
63019	8695	-0.20	0.00	-0.43	0.06	-0.35	0.03					-0.70*	0.28

Notes: Elast. = Elasticity
*All the elasticities marked with * are not based on delta coefficients which are significantly different from zero (i.e. the coefficients p-value are over 0,1). Hence, these estimates are only affected by the cost shares.*

Table AII.2 Shadow (SES) and Morishima elasticities of substitution (MES)

IND	Nro of obs	SES, CAP-LAB Elast.	S.e.	MES, LAB-CAP Elast.	S.e.	MES, CAP-LAB Elast.	S.e.	MES, LAB-OSERV Elast.	S.e.	MES, OSERV-LAB Elast.	S.e.	MES, CAP-OSERV Elast.	S.e.	MES, OSERV-CAP Elast.	S.e	SES, all energy inputs Elast.	S.e.
1	20886	0.48	0.03	0.43	0.12	0.67	0.04	0.10	0.05	0.40	0.28	-0.14	0.25	0.13	0.28		
2	13228	0.47	0.04	0.43	0.13	0.72	0.04	0.25	0.13	0.45	0.04	-0.04	0.56	0.23	0.04		
5	2731	0.38	0.09	0.33	0.03	0.64	0.11	0.19	0.04	0.48	0.11	-0.13	0.18	0.04	0.11		
20	15796	0.39	0.04	0.37	0.01	0.56	0.03	0.33	0.01	0.46	0.03	0.14	0.05	0.23	0.03		
22	22629	0.44	0.03	0.41	0.01	0.60	0.02	0.50	0.01	0.59	0.02	0.31	0.04	0.32	0.02		
24	2457	0.43	0.07	0.40	0.02	0.67	0.34	-0.11	0.03	0.17	0.34	-0.45	0.12	0.00	0.34	1.57*	0.54
25	4652	0.40	0.05	0.36	0.02	0.64	0.07	0.24	0.03	0.48	0.07	-0.13	0.08	-0.04	0.07		
26	5071	0.39	0.06	0.36	0.02	0.66	0.20	0.83	0.02	0.51	0.20	0.43	0.07	0.12	0.20	6.01	1.46
28	28453	0.43	0.02	0.41	0.01	0.66	0.02	0.92	0.01	0.40	0.02	0.68	0.03	-0.69	0.02		
29	20025	0.39	0.03	0.37	0.01	0.56	0.02	0.38	0.01	0.51	0.03	0.20	0.04	0.24	0.03		
32	3189	0.49	0.06	0.48	0.02	0.56	0.08	0.41	0.04	0.51	0.08	0.33	0.11	0.38	0.08		
33	7005	0.61	0.04	0.62	0.01	0.55	0.06	0.52	0.03	0.46	0.06	0.59	0.07	0.68	0.06		
37	423	0.92	0.20	0.97	0.06	0.67	0.19	0.60	0.09	0.42	0.19	0.89	0.31	1.14	0.19		
41	6610	0.65	0.03	0.64	0.02	0.65	0.10	0.46	0.03	0.54	0.10	0.45	0.13	0.56	0.10		
51	117084	0.51	0.01	0.50	0.00	0.60	0.01	0.36	0.01	0.48	0.01	0.25	0.02	0.38	0.01		
61	2470	0.54	0.07	0.51	0.02	0.64	0.08	0.50	0.03	0.62	0.08	0.36	0.14	0.38	0.08		
62	464	0.56	0.10	0.52	0.01	0.66	0.14	0.59	0.05	0.72	0.14	0.45	0.20	0.39	0.14		
65	10099	0.70	0.02	0.71	0.01	0.68	0.08	0.59	0.02	0.59	0.08	0.62	0.10	0.71	0.08		
66	319	0.41	0.22	0.34	0.03	0.68	0.27	0.22	0.05	0.60	0.27	-0.12	0.41	-0.03	0.27		
71	8139	0.56	0.03	0.52	0.01	0.64	0.06	0.43	0.02	0.60	0.06	0.30	0.09	0.35	0.06		
72	38996	0.60	0.02	0.60	0.01	0.61	0.03	0.44	0.01	0.47	0.03	0.43	0.04	0.57	0.03		
73	2282	0.56	0.08	0.56	0.02	0.58	0.07	0.80	0.03	0.78	0.07	0.77	0.12	0.58	0.07		
80	9866	0.48	0.05	0.46	0.01	0.60	0.04	0.41	0.02	0.53	0.04	0.27	0.07	0.35	0.04		
90	3852	0.30	0.07	0.24	0.02	0.71	0.04	0.88	0.02	0.46	0.04	0.41	0.09	-0.72	0.04		
103	2060	0.31	0.12	0.26	0.03	0.69	0.04	0.33	0.02	0.48	0.04	-0.10	0.14	0.11	0.04		
134	2792	0.50	0.09	0.46	0.03	0.66	0.04	0.53	0.02	0.62	0.05	0.33	0.14	0.37	0.05		
156	10949	0.43	0.04	0.40	0.01	0.63	0.05	0.93	0.02	0.23	0.05	0.71	0.06	-0.74	0.05		
179	10731	0.35	0.06	0.33	0.02	0.54	0.04	0.29	0.02	0.42	0.04	0.08	0.08	0.20	0.04		
212	1003	0.19	0.12	0.14	0.04	0.66	0.10	-0.29	0.06	0.13	0.10	-0.80	0.16	-0.27	0.10		
271	292	0.60	0.22	0.60	0.07	0.92	1.62	0.66	0.08	0.48	1.63	0.32	0.39	0.11	1.63	0.23*	32.5
301	2984	1.35	0.15	1.40	0.04	0.60	0.08	0.87	0.04	0.42	0.08	1.67	0.18	1.85	0.08		

IND	Nro of obs	SES, CAP-LAB Elast.	S.e.	MES, LAB-CAP Elast.	S.e.	MES, CAP-LAB Elast.	S.e.	MES, LAB-OSERV Elast.	S.e.	MES, OSERV-LAB Elast.	S.e.	MES, CAP-OSERV Elast.	S.e.	MES, OSERV-CAP Elast.	S.e	SES, all energy inputs Elast.	S.e.
345	5430	0.41	0.07	0.39	0.02	0.54	0.04	0.44	0.02	0.53	0.04	0.29	0.09	0.30	0.04		
361	7188	0.38	0.06	0.37	0.02	0.57	0.05	0.15	0.03	0.32	0.05	-0.05	0.08	0.20	0.05		
501	11389	0.52	0.04	0.49	0.01	0.64	0.04	0.37	0.02	0.52	0.04	0.22	0.06	0.35	0.04		
502	42078	0.35	0.02	0.34	0.01	0.49	0.04	0.00	0.03	0.20	0.04	-0.16	0.04	0.13	0.04		
521	117993	0.41	0.01	0.40	0.00	0.52	0.02	0.09	0.01	0.26	0.02	-0.03	0.02	0.23	0.02		
527	4720	0.48	0.08	0.47	0.03	0.59	0.14	-0.26	0.07	-0.07	0.14	-0.37	0.15	0.29	0.14		
551	10909	0.53	0.03	0.50	0.01	0.60	0.06	0.36	0.02	0.53	0.06	0.27	0.07	0.33	0.06		
553	42968	0.48	0.02	0.46	0.01	0.72	0.04	-0.23	0.02	0.16	0.04	-0.48	0.04	0.07	0.04		
633	7348	0.52	0.04	0.49	0.01	0.62	0.05	0.48	0.02	0.60	0.05	0.36	0.08	0.37	0.05		
641	1400	0.52	0.16	0.50	0.03	0.69	0.06	0.58	0.03	0.66	0.06	0.40	0.17	0.43	0.06		
642	2995	0.41	0.08	0.35	0.02	0.66	0.05	0.43	0.02	0.60	0.05	0.12	0.12	0.18	0.05		
671	14235	0.65	0.02	0.63	0.01	0.68	0.06	0.46	0.01	0.58	0.06	0.41	0.08	0.51	0.06		
672	1777	0.94	0.13	0.97	0.03	0.61	0.12	0.83	0.05	0.55	0.12	1.18	0.19	1.25	0.12		
741	67561	0.48	0.02	0.48	0.00	0.56	0.02	0.32	0.01	0.41	0.02	0.23	0.03	0.38	0.02		
742	41215	0.44	0.02	0.43	0.01	0.60	0.02	0.28	0.01	0.41	0.02	0.11	0.03	0.30	0.02		
743	2422	0.42	0.08	0.39	0.02	0.60	0.08	0.38	0.03	0.55	0.08	0.18	0.12	0.22	0.08		
744	15134	0.51	0.04	0.49	0.01	0.64	0.02	0.45	0.01	0.53	0.02	0.30	0.05	0.40	0.02		
745	4920	0.79	0.07	0.78	0.02	0.84	0.09	0.77	0.04	0.84	0.09	0.71	0.11	0.72	0.09		
746	2124	0.51	0.12	0.49	0.03	0.72	0.08	0.21	0.04	0.37	0.08	-0.02	0.15	0.33	0.08		
747	9089	0.53	0.06	0.51	0.02	0.90	0.04	0.35	0.02	0.60	0.04	-0.03	0.07	0.27	0.04		
748	21249	0.55	0.03	0.53	0.01	0.68	0.02	0.40	0.01	0.51	0.02	0.25	0.04	0.42	0.02		
851	30343	0.48	0.03	0.46	0.01	0.57	0.03	0.41	0.01	0.50	0.03	0.30	0.04	0.37	0.03		
852	1344	0.63	0.11	0.63	0.03	0.68	0.09	0.27	0.05	0.36	0.09	0.22	0.18	0.54	0.09		
853	11011	0.68	0.03	0.67	0.01	0.72	0.11	-0.29	0.07	-0.08	0.11	-0.34	0.09	0.46	0.11		
935	12624	0.43	0.05	0.42	0.02	0.66	0.06	-0.11	0.03	0.16	0.06	-0.35	0.07	0.15	0.06		
2725	830	0.28	0.15	0.23	0.05	0.73	0.29	0.27	0.05	0.51	0.29	-0.19	0.18	0.01	0.29	0.96*	0.74
3626	3286	0.19	0.09	0.15	0.02	0.68	0.07	-0.17	0.03	0.22	0.07	-0.70	0.12	-0.24	0.07		
4013	3033	0.57	0.06	0.50	0.01	0.77	1.04	-0.16	0.02	0.54	1.04	-0.81	0.16	-0.17	1.04	1,0*	0.14
4501	20010	0.55	0.03	0.51	0.01	0.76	0.02	0.31	0.01	0.49	0.02	0.06	0.04	0.33	0.02		
4502	77013	0.44	0.02	0.42	0.01	0.64	0.01	0.44	0.00	0.53	0.01	0.21	0.02	0.33	0.01		
4509	58953	0.55	0.02	0.54	0.01	0.68	0.01	0.32	0.01	0.44	0.01	0.17	0.02	0.41	0.01		
6023	66697	0.57	0.02	0.54	0.01	0.80	0.02	-0.03	0.01	0.26	0.02	-0.28	0.02	0.26	0.02		

IND	Nro of obs	SES, CAP-LAB Elast.	S.e.	MES, LAB-CAP Elast.	S.e.	MES, CAP-LAB Elast.	S.e.	MES, LAB-OSERV Elast.	S.e.	MES, OSERV-LAB Elast.	S.e.	MES, CAP-OSERV Elast.	S.e.	MES, OSERV-CAP Elast.	S.e	SES, all energy inputs Elast.	S.e.
7012	11110	0.53	0.03	0.48	0.01	0.67	0.06	0.18	0.01	0.53	0.06	0.00	0.07	0.14	0.06		
7031	8694	0.40	0.05	0.38	0.01	0.57	0.05	0.09	0.02	0.30	0.05	-0.11	0.07	0.17	0.05		
7032	16846	0.45	0.04	0.43	0.01	0.69	0.03	0.14	0.01	0.36	0.03	-0.12	0.05	0.21	0.03		
7512	211	0.92	0.49	0.96	0.10	0.46	0.15	0.89	0.07	0.73	0.15	1.39	0.60	1.12	0.15		
9214	9688	0.52	0.05	0.50	0.01	0.68	0.03	0.51	0.01	0.61	0.03	0.33	0.07	0.40	0.03		
9267	10555	0.58	0.04	0.56	0.01	0.70	0.04	0.17	0.02	0.38	0.04	0.03	0.06	0.35	0.04		
21121	620	0.53	0.13	0.45	0.04	0.97	0.21	-0.05	0.05	0.49	0.21	-0.59	0.20	-0.03	0.21	1,0*	0.01
63019	8695	0.52	0.5	0.48	0.01	0.70	0.03	0.48	0.01	0.58	0.03	0.27	0.06	0.40	0.03		

Notes: Elast. = Elasticity
All the elasticities marked with * are not based on delta coefficients which are significantly different from zero (i.e. the coefficients p-value are over 0,1). Hence, these estimates are only affected by the cost shares.

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