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An Econometric Input-Output Model for EU Countries Based on Supply and use Tables: The Production Side

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Abstract:
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Keywords: Supply and use tables, Econometric input-output, Production

Archives: CGE models and econometrics

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An Econometric Input-output model for EU countries based on Supply & Use tables: the production side

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1 INTRODUCTION

There exists a vast amount of literature dealing with the interrelations among the demand of factors of productions, how to model such demand from the standpoint of the economic theory underpinnings and how to proceed in the phase of empirical research. This paper does not address such general aspects of production theory but draws from the recent literature; the context of this paper is confined instead to the practical implementation within an Econometric Input-Output (EIO) model, to some of the available choices with their consequences, and to the discussion of the empirical results in a prototype application.

For the general characteristics of the Input-Output (IO) structure of this model we refer to Kratena & Streicher (2009), who recently introduced a model prototype based on Supply and Use Tables (SUT) rather than Symmetric IO Tables (SIOT) which can be programmed in GAMS and simultaneously solved for prices and quantities as a constrained non-linear system. We make use of the block-by-block flexibility allowed by this sort of operational specification to go beyond the linear Leontief paradigm and integrate a flexible production function that relates the use of four factors of production (labour, energy, domestic and imported materials) to their prices and to the available capital stock taken as short-term fixed.

This paper contributes to the existing literature by introducing in the production function several specific features that include: a differentiation between imported and domestic materials thereby dealing with international outsourcing and dislocation of production activities; the representation of different sources of technical change (autonomous and embodied); the application of the EU KLEMS data for capital stock taking into account specific issues of the measurement of capital inputs (hedonic prices). The framework introduced can in principle be easily extended by allowing for non-constant returns to scale, including an investment function and mark-up pricing, consistently with the concept of imperfect competition à la Dixit/Stiglitz. Section 2 introduces the chosen specification of the production function in the context of the existing literature; section 3 reports on the empirical estimations for three European countries, including some empirical problems to be considered when the extending the framework beyond the constant returns to scale simplification; section 4 integrates the estimated production block in a prototype econometric input-output model and presents a the results of a very stylised simulation; section 5 elaborates on further potential extensions of the presented framework and concludes.

2 PRODUCTION FUNCTION SPECIFICATION

The demand for factors of production and the modelling of producer behaviour by characterising supply and demand has been investigated since long. One of the first production functions, the well known Cobb-Douglas functional form, was proposed already in 1928 (Cobb & Douglas, 1928). However, the Cobb-Douglas specification is not able to reflect the information contained in historical data series, as by definition it assumes unitary own price elasticities and zero cross-price elasticities. Arrow et al. (1961) developed the more general CES function which allows income elasticities to lie between zero and infinity. Especially from the early 1950s until the late 1970s, the number of available functional forms has increased significantly. For example, the translog specification, allowing for more than two inputs and variable elasticities of substitution was presented in the 70s (Griliches & Ringstad, 1971, Berndt & Christenson, 1973, Christensen, et al. 1973). Already in 1987, Griffin et al. (1987) presented about 20 different functional forms and discussed the problem of selecting an adequate form for production function applications.

In practice, today, the Cobb-Douglas and the CES functions are most frequently used due to convenience. In CGE modelling, CES functions are applied, typically. The CES cost function for four factors of production K, L, E, M (capital, labour energy and materials) can be written as

$$C = \left(\frac{Y}{A}\right)^{\frac{1}{\nu}} \left[\alpha_K^{\frac{1}{1+\rho}} p_K^{\frac{\rho}{1+\rho}} + \alpha_L^{\frac{1}{1+\rho}} p_L^{\frac{\rho}{1+\rho}} + \alpha_E^{\frac{1}{1+\rho}} p_E^{\frac{\rho}{1+\rho}} + \alpha_M^{\frac{1}{1+\rho}} p_M^{\frac{\rho}{1+\rho}} \right]^{-1+\rho/\rho} \tag{1}$$

This functional form relates the cost to the output Y with the parameter ν reflecting the non-constant returns to scale, to the cost shares α of the benchmark factors of production, to the prices p of the factors of production, and to the elasticity of substitution between inputs, where the Allen (partial) elasticity of substitution between any two inputs can be obtained as $\sigma = 1/(1+\rho)$. Although the CES function is less restrictive than the Cobb-Douglas function (special case of the CES function with $\rho = 0 \Leftrightarrow \sigma = 1$) and the linear Leontief function (special case of the CES function with $\sigma = 0$), it is still relatively stylised as it imposes elasticities of substitution that are constant through time and equal among different pairs of inputs (in fact, CGE models customarily use nested CES functions to overcome the latter – hardly desirable – restriction). There exists a more general class of production functions, including the Diewert or Generalised Leontief (GL) function, the Transcendent Logarithmic (Translog) function and others, that have a flexible functional form permitting the partial elasticities of substitution between inputs to vary, and to vary along time. In this paper we follow the stream of literature that champions the translog function as a form that allows plenty of flexibility but at the same time retains sufficient compactness and tractability.

The translog cost function can be viewed as a second order Taylor's series approximation of an arbitrary cost function, and for the general non-homothetic (not restricted to constant returns to scale) case equivalent to eq. (1) it can be written in compact form as

$$\ln C = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j + \alpha_Y \ln Y + \frac{1}{2}\gamma_{YY}\left(\ln Y\right)^2 + \sum_{i=1}^{n} \gamma_{iY} \ln p_i \ln Y \qquad (2)$$

where the indices *i* and *j* run over the four factors of production *K, L, E, M.*

We note at this point that expressions (1) and (2) both assume that all factors of production are fully flexible, which implies they can adapt instantaneously to new conditions. This is especially unrealistic in the case of fixed capital, and indeed it is an assumption that can end up largely at odds with the storyline that is implicit in the data once one tests it in the empirical estimation of the function from historical series of production data. For this reason we follow a further stream of research that deals explicitly with the (short-term) fixity of certain inputs; we will assume in fact that capital goods are fixed in the short term and determined by a different mechanism that allows for long-term adjustment of the capital stock. Such long-term adjustment mechanism can typically be represented by an ex-post adjustment of the capital stock in response to the emerged non-optimality of the stock given observed price of capital relative to the other factors of production, and is presently not part of this paper. We will also make two additional assumptions: the first one is the restriction to constant returns to scale, which is not necessary in general but for this model prototype will help us avoiding trouble with the long-term regularity of the production function; the second one introduces the explicit consideration of autonomous technical change by including a further trend term.

Due to the exclusion of fixed capital from the cost function, the left-hand side of eq. (2) will then be the sole Variable Cost (VC) rather than total cost C. We also make use of the homogeneity restriction of the translog function that allows us to drop the n^{th} factor of production from the equation, dividing all prices by p_n, as the determination of n factors of production is established once n-1 factors are estimated. Equation (2) becomes then

$$\log VC = \alpha_0 + \alpha_Y \log Y + \sum_i \alpha_i \log(p_i / p_n) + (1-\alpha_Y)\log x_K + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2$$
$$+ \sum_i \frac{1}{2}\gamma_{ii}(\log(p_i / p_n))^2 + \sum_{i,j}\gamma_{ij}\log(p_i / p_n)\log(p_j / p_n)$$
$$+ \sum_i \rho_{Ki}\log\left(\frac{x_K}{Y}\right)\log(p_i / p_n) + \rho_{YK}\left(\log Y \log x_K - \frac{1}{2}(\log Y)^2 - \frac{1}{2}(\log x_K)^2\right) + \tag{3}$$
$$+ \sum_i \rho_{ti} t \log(p_i / p_n) + \rho_{tK} t \log\left(\frac{x_K}{Y}\right)$$

where α_t and α_{tt} are the linear and square coefficients of the total factor productivity growth term, and the pure terms depending on capital stock x_K and output Y are replaced by the ratio of fixed capital over output as a consequence of constant returns to scale. Factor demand can be now derived by applying Shephard's lemma which states that demand Q_i for factor i is equal to the first derivative of the cost function with respect to the price p_i of factor i. With constant returns to scale this yields:

$$\frac{p_i Q_i}{VC} = \left[\alpha_i + \sum_j \gamma_{ji}\log(p_j / p_n) + \rho_{Ki}\log\left(\frac{x_K}{Y}\right) + \rho_{ti} t\right] \tag{4}$$

In the next section we report the results of the estimation of the translog production function as a system of three equations (eq. 4) for the flexible factors of production: labour L, energy E, non-energy imports M^M and non-energy domestic intermediates M^D.

Note that the elasticity parameters directly estimated, γs, can be positive or negative, whereas microeconomic theory dictates restrictions on price elasticities (own price elasticities must be restricted to negative values). Own and cross price elasticities can be computed from the γs and tested for consistency by applying the following expression:

$$\begin{cases} \varepsilon_{ii} = \dfrac{\partial \log x_i}{\partial \log p_i} = \dfrac{s_i^2 - s_i + \gamma_{ii}}{s_i} \\ \varepsilon_{ij} = \dfrac{\partial \log x_i}{\partial \log p_j} = \dfrac{s_i s_j + \gamma_{ij}}{s_i} \end{cases} \qquad 5)$$

where s_i is the share of utilisation of factor i over the total variable cost VC. Further note that, even if the γs are constant through time and symmetric with respect to the indices i and j, elasticities are not due to the varying shares.

In addition to the symmetry restriction of the cross price elasticity parameters γ ($\gamma_{ij} = \gamma_{ji}$), the properties of the translog function include the additivity and homogeneity of degree zero conditions. By additivity, $\boldsymbol{\Sigma_i \alpha_i = 1}$ and $\boldsymbol{\Sigma_i \gamma_{ij} = 0}$, while homogeneity of degree zero requires that $\boldsymbol{\Sigma_j \gamma_{ij} = 0}$.

The homogeneity restriction allows us to estimate only n-1 of the n arguments of the production function, while the factor demand equation of nth argument is dropped in the econometric estimation. The additivity and homogeneity restrictions are then not observed but exploited to obtain the coefficients and constants of the omitted factor, which is chosen to be domestic intermediates.

From the homogeneity and additivity restrictions it follows that the own and cross price elasticity parameters of the omitted factor can be calculated as:

$$\begin{cases} \gamma_{Dj} = -\gamma_{Mj} - \gamma_{Ej} - \gamma_{Lj} \\ \gamma_{DD} = -\gamma_{DL} - \gamma_{DE} - \gamma_{DM} \end{cases} \tag{6}$$

The own and cross price elasticities are then also calculated according to eq. 5

3 ECONOMETRIC ESTIMATION

We carried out the econometric estimation of a system of three equations, one each for the demand of labour *L*, energy *E* and non-energy imports M^M as spelled out in equation 4. The equation for domestic non-energy intermediates M^D is dropped and all prices are defined relative to the price index for domestic non-energy intermediates. In theory it would also be possible to estimate an extended system comprising, in addition to the factor demand equations, the total variable cost equation (eq. 3), or even to obtain all the parameters necessary for the model by estimating the variable cost equation alone; the contemporary estimation of the extended system would improve the efficiency of the estimator, but in this case it has been dropped due to some multicollinearity problems in the estimation. The explicit equations for the shares of labour cost, energy cost and cost of imports without energy over total variable costs are spelled out from (4) as equations 7, 8 and 9 below.

$$\frac{p_L L}{VC} = \left[\alpha_L + \gamma_{LL} \log(p_L / p_D) + \gamma_{EL} \log(p_E / p_D) + \gamma_{ML} \log(p_M / p_D) + \rho_{KL} \log\left(\frac{x_K}{Y}\right) + \rho_{tL} t \right] \tag{7}$$

$$\frac{p_E E}{VC} = \left[\alpha_E + \gamma_{EE} \log(p_E / p_D) + \gamma_{EL} \log(p_L / p_D) + \gamma_{EM} \log(p_M / p_D) + \rho_{KE} \log\left(\frac{x_K}{Y}\right) + \rho_{tE} t \right] \tag{8}$$

$$\frac{p_M M^M}{VC} = \left[\alpha_M + \gamma_{MM} \log(p_M / p_D) + \gamma_{EM} \log(p_E / p_D) + \gamma_{ML} \log(p_L / p_D) + \rho_{KM} \log\left(\frac{x_K}{Y}\right) + \rho_{tM} t \right] \tag{9}$$

The estimation was carried out for the three model countries Germany (DE) Denmark (DK) and Finland (FI), and the necessary information was obtained from national accounts (EUROSTAT), with additional KLEM data from the EUKLEMS project[1] and imports data by commodity (prices and quantities) from COMTRADE[2], adapted by aggregation to CPA 2-digit classification and by removal of outliers[3]. Time series of use matrices for imports were interpolated from available use matrices for imports (mostly available every five years) and from the time series of commodity import flows aggregated by CPA classification following Ekholm and Hakkala (2005).

Intermediates from use tables, both domestic and imported, include energy inputs (CPA 10 coal, 11 oil & gas, 12 uranium, 23 refinery products, 40 electricity & gas distribution). These inputs were separated from the domestic and imported intermediates and aggregated together as energy inputs of any origin; price indices for the modified aggregates were calculated as logarithmic indices (Stone's price index). The following list resumes the main data used and the sources.

$p_S S$	Intermediate inputs, current prices, from EUKLEMS
p_S	Intermediate inputs, price index, from EUKLEMS
$p_L L$	Labour input, current prices, from EUKLEMS
p_L	Labour input , price index, from EUKLEMS
$p_E E$	Energy inputs, current prices, from EUKLEMS
p_E	Energy inputs, price index, from EUKLEMS
$p_{nE} S_{nE}$	Intermediate inputs without energy, current prices, from EUKLEMS
p_{nE}	non-energy intermediate inputs, price index. Calculated from Stone price index formula: $\log(p_S) = p_{nE}S_{nE}/p_S S * \log(p_{nE}) + p_E E/p_S S * \log(p_E)$
$p_M M^M$	imports by industry without energy. Own estimation
$p_D M^D$	domestic intermediates without energy. Own estimation
p_M	non-energy imported intermediates, price index. Calculated from estimated import matrices & import prices by CPA
p_D	non-energy domestic intermediates, price index. Calculated from Stone price index formula: $\log(p_{nE}) = p_M M^M / p_{nE}S_{nE} * \log(p_M) + p_D M^D / p_{nE}S_{nE} * \log(p_D)$
x_k	Capital stock, from EUKLEMS (limited sectoral breakdown)
Y	Output at factor costs, from EUKLEMS

[1] See: www.euklems.net.
[2] United Nations Commodity Trade Statistics Database. See: http://comtrade.un.org/
[3] By courtesy of Gerhard Streicher, Joanneum Research, Vienna.

An important issue that arises is the data availability over time for the different variables, which varies. Even by limiting the country coverage to three countries for which comparatively good statistics are available, some of the variables are available only for short time series; coverage of the variables was ultimately complete only for the eleven years 1995-2005. In order to improve the statistics we pooled then the data for the three countries, and estimated a system of nine equations (three per country) in which all variables were pooled except the constants α's, which remained the only country specific parameter.

The system of 3 equations is defined over 18 coefficients and constants; however, due to the symmetry restriction of the cross price elasticity parameters γ ($\gamma_{ij} = \gamma_{ji}$), only 15 independent parameters need be estimated, which become 21 once the 6 additional constants for the pooled system of three countries are added.

The estimations were carried out with the seemingly unrelated (SUR) estimator (Zellner, 1962), a system estimator that takes into account the contemporaneous correlation of residuals between the factor demand equations.

The classification of industries of the model follows the 2-digit NACE classification, comprising 59 sectors. However, the KLEM production paradigm is adequate mainly for the manufacturing industries (NACE sectors 15 through 45), but is not necessarily a useful representation for instance for the services sectors. Accordingly, we estimated translog production functions for the NACE sectors 15, 17, 18, 20, 21, 22, 24-29, 31-36 and 45. Energy supplying sectors 23 and 40 have been excluded since their output is an exogenous input in the production function and several small sectors with highly variable outputs, such as NACE 16 tobacco, 19 leather products, and 37 recycling, have been excluded too because the output variability could not be satisfactorily explained by the variables of the production function.

The following of this section reports on the results of the estimations, showing a selection of the estimated values and diagnostics. Also shown are a subset of the own- and cross-price elasticities computed as from eq. 5 based on the γ parameters and on the shares of factor demands. Table 1 shows the estimates of the own- and cross-price elasticity parameters of energy, labour and imported materials for the manufacturing sectors. Most estimates (88 out of 114) are significant at the 95% confidence level. We should note however that eight times a constraint had to be added to the own-elasticity parameters, reflected in associated T-statistics approaching infinity (n.a. in Table 1), in order to guarantee negative own price elasticities especially of the labour input. Since the factor demand equation for domestic intermediates is dropped and its parameters are retrieved by imposing system restrictions, constraints on the domestic materials price elasticities are not imposed. Those elasticities turn out however well behaved with the exception of sector 18 (clothes), slightly positive.

Table 1 about here

The computed own-price elasticities of the four production factors (energy, labour, imported and domestic materials) are shown for the different sectors in Table 2. The elasticities show a large variance across sectors and factors. Even though some elasticities are suspiciously high (e.g. -3.38 for own-price elasticity of energy for Radio, television and communication equipment), most of them are in the range of those commonly found in the literature. Very low (e.g. -0.002 for own-price elasticity of energy for Basic metals) elasticity values are generally associated to constrains imposed. For the majority of sectors (11 out of 19), the own-price elasticity of energy is higher than the own-price elasticities of labour, imported and domestic materials. It is noticeable that this does not hold in the case of energy intensive sectors such as Pulp, paper and paper products, and Other non-metallic mineral products.

Table 2 about here

The cross-price elasticities of energy-labour (ε_{EL}), labour-energy (ε_{LE}), energy-imported materials (ε_{EM}), imported materials-energy (ε_{ME}), labour-imported materials (ε_{LM}), and imported materials-labour (ε_{ML}) are displayed in Table 3. The cross-price elasticities are heterogeneous and range from very high negative (-6.21) to very high positive (9.04) values, although in most cases the cross price elasticities are small (<1) in absolute value, as one would expect. Consistently with equation (5), for every sector *s* and two production factors *i* and *j*, the cross elasticity $\varepsilon_{ij}(s)$ and its symmetric $\varepsilon_{ji}(s)$ are of the same sign since shares can only be positive and γ's are symmetric. In the case of the pair $\varepsilon_{EM}/\varepsilon_{ME}$, the majority of the sectors show positive elasticities. It means that for most sectors (namely 15, 17, 20, 21, 24, 25, 26, 28, 29, 32, 34, 36 and 45) imported materials are substitute for energy and vice versa. For all sectors, ε_{EM} is much higher in absolute term than ε_{ME}, which is the result of the higher share of imported materials compared with the energy, with this difference becoming much smaller for energy intensive sectors like “pulp and paper”, and “other non-metallic minerals”.

This empirical evidence of energy-imports substitutability is policy relevant as it relates to the question of carbon leakage as a consequence to asymmetric climate policies (ETS in the EU). The carbon price acts like a higher energy price and leads to substitution of energy by imports. On the other hand the result of complementarity of labour and imports (see below) would suggest that outsourcing does not harm the domestic labour market, although this result might be biased by the lack of differentiation between different labour skills (outsourcing hurts unskilled labour).

For energy and labour inputs, ε_{EL} is in all sectors much higher in absolute term than ε_{LE}, which is, again, the result of the higher labour share compared with the energy share. There is however no clear direction for the sign of the cross elasticity pair $\varepsilon_{EL}/\varepsilon_{LE}$, which involves labour can be a substitute or compliment to energy depending on the sector. In particular with energy intensive sectors, the results show that labour is a substitute for energy in “pulp and paper”, “other non-metallic minerals”, and “basic metals”, but is complementary to energy in “chemicals”. Regarding the pair $\varepsilon_{LM}/\varepsilon_{ML}$, the majority of the sectors (namely 15, 20, 21, 22, 26, 27, 29, 32, 33, 34, 35, and 45) show negative cross elasticities. It implies that imported materials are mainly complementary to labour and vice versa.

Table 3 about here

Table 4 shows the cross-price elasticities of domestic materials-imported materials (ε_{DM}), imported materials- domestic materials (ε_{MD}), domestic materials-energy (ε_{DE}), energy-domestic materials (ε_{ED}), domestic materials-labour (ε_{DL}), and labour-domestic materials (ε_{LD}). As is the case for the cross-price elasticities for energy-labour, energy-imported materials, and labour-imported materials, the elasticities range from negative (-3.27) to positive (4.35) values, but in the majority of cases the elasticities are small (<1) in absolute value.

In the case of the pair $\varepsilon_{DM}/\varepsilon_{MD}$, all sectors with the exception of two (17, 18; textiles and wearing apparel) show positive cross-price elasticities indicating that imported and domestic materials are substitutes. The exception of sectors 17 and 18 is somehow challenging to explain. Indeed a deeper observation of the data used in the estimation reveals erratic patterns of increasing-decreasing import shares and import prices in those sectors across the three countries.

For labour and domestic materials, ε_{DL} and ε_{LD} are positive (labour and domestic materials are substitutes) except for the sectors 27 (basic metals) and 28 (fabricated metal products).

When we look at domestic materials and energy, again, a majority of the sectors show positive elasticities for ε_{DE} and ε_{ED}.

Note also that ε_{jD} is higher than ε_{Dj} for nearly all sectors and all factors of production *j*, which again follows from the fact that that the share of domestic materials is almost invariably higher than the share of any other production factor.

Table 4 about here

Table 5 give the estimates of own price elasticities of energy intensity (ε_{EE}) from 1995 to 2005. Contrary to what we would have with a CES function, the elasticities are time dependent and in the majority of cases become more negative with time, reflecting *increases* in energy intensity. In energy intensive industries such as the car industry (motor vehicles), however, the energy efficiency *gains* experienced over time are reflected by *less* elastic energy demand with time.

Table 5 about here

Table 6 presents the estimates of parameters for embodied technical change in energy (ρ_{KE}), labour (ρ_{KL}) and imported materials (ρ_{KM}) as well as autonomous technical change in energy (ρ_{tE}), labour (ρ_{tL}) and imported materials (ρ_{tM}). The results are somehow contrasted. In general, the autonomous technical change parameters are more often significant than the embodied ones. A negative sign for ρ_{KE} and ρ_{KL} is found only in 6 out of 19 sectors and 2 out of 19, respectively, and is never significant except in one case; conversely, significant positive values for ρ_{KE}, indicating capital-energy complementarity, are found in eight industries. ρ_{KM} shows significant statistics in eleven cases, of which eight with positive sign and two negative. Such positive capital-imports correlation is perhaps difficult to explain in terms of embodied technical change and may have to do with some multicollinearity (capital with time), which may also affect the poor statistics of the other factor-capital coefficients. In the case of autonomous change, the anticipated negative sign for ρ_{tE} and ρ_{tL} is found in 6 out of 19 sectors and 18 out of 19, respectively, and is always significant except in four cases. As a result, energy-saving technical change (both embodied and autonomous) is shown only for a limited number of manufacturing sectors whereas labour-saving technical change is found in almost all sectors as an autonomous change (labour productivity gains do not show significant correlation with the aggregate capital stock). Conversely, and in line with expectations, (ρ_{tM}) has positive sign always except for sector 17 and is always significant except for sectors 22, 24, 32, and 35. This observation appears as a clear reflection of the globalisation process.

Table 6 about here

4 PRODUCTION FUNCTION AT WORK IN THE I-O MODEL

Following Kratena and Streicher (2009), the estimated factor demand functions 7, 8 and 9 are incorporated in a system of equations that is iteratively solved for quantities and prices simultaneously until convergence is reached. We refer to Kratena and Streicher (2009) for the description of the complete system of equations. In this section we only outline the logical framing of the factor demand function in the overall computational sequence:

1. sectoral output is derived from total demand (in basic prices) for domestically produced goods using the market shares matrix (supply table in coefficients form)
2. capital costs are obtained as fixed share of the sectoral output
3. variable costs are total costs less capital costs
4. demands for labour (wages), energy and imported materials are calculated as shares of variable costs through equations 7, 8, 9.
5. Demand for domestic materials is calculated by difference
6. final demand for commodities by user: aggregate government and NPISH consumption as a share of total value added, aggregate household consumption as a share of wages and of capital revenues. Investment demand by sector as a fixed share of sectoral output (simple accelerator model). Demand for exports is taken as exogenous
7. final demand by commodity is obtained by splitting the aggregate final demand by user according to the commodity structure (use table), investment by commodity through the structure of an estimated investment matrix. Household demand is further modelled by including an Almost Ideal Demand System (see Kratena (2) et al, 2009)
8. demand in purchasers' prices is deflated to basic prices through two matrices: taxes less subsidies on commodities, and trade and transport margins. Net taxes are then

aggregated in a dummy "tax receiving sector", margins paid are redistributed to the margin receiving sectors according to fixed shares per sector

9. import prices are exogenous
10. output price is a weighed average of costs for intermediate inputs, wages, and other components of value added
11. domestic commodity price is a weighed average of output prices (weights given by market shares of sectors)
12. use price of commodity by user is a weighed average of commodity prices (weights given by the structure of the use matrix)

Since steps 1-8 are iterated to convergence, a shock can be introduced at different stages of the sequence depending on the special conditions of the simulation. A decrease of import prices, for instance, would first effect an imbalance in the factor demand equations (step 4), increasing the share of imports in production and decreasing (or increasing) the share of the other inputs j according to the cross-price elasticities ε_{jM}. The output price (step 10) is affected by the changes in input shares and by the decrease of import prices. Commodity prices are then affected in step 11, and the price experienced by all users is changed in step 12. Final demand by commodities will then be affected both by changed prices and changed aggregate demand, as with changed sectoral output (step 1) also labour compensation changes and with it disposable income (step 6).

Although this modelling scheme reaches a long way compared to the static IO model, if we compare it to the standard CGE model one important step is still missing: we have just seen how a price signal ripples through the system to produce demand (quantity) effects; this change in demand, however, does not have any further effects on prices, in other words the supply of goods is still as perfectly elastic as in the basic Leontief model. What makes prices respond to quantities demanded is the pressure exerted on scarce factors of production (labour, capital, land etc.). In order to close this gap, we would need to integrate in the model a set of equations not only for factor *demand* but also for factor *supply*.

5 CONCLUSIONS AND FURTHER CONSIDERATIONS

This paper reports on the estimation of a system of factor demand equations in the translog specification that include four factors of production (labour, energy and domestic and imported materials) as components of total variable costs in each industry, and on how such factor demand equations can be incorporated in an econometric input-output model. The choice of model has been made keeping in mind the availability of the necessary data for EU countries from NSI's and especially from Eurostat and some additional prominent data sources such as EUKELMS, with a view to proposing a model generally workable for EU countries. The prototype presented has been implemented for three EU countries and the estimation results are generally in the range of the literature values. The adopted cost function explicitly accounts only for variable costs, in accordance with the assumption that fixed capital is fixed in the short term (it is an exogenous parameter in the variable costs function) as its adjustment to price signals occurs on a longer time scale. The model we introduced so far shows therefore an evident limp by the missing investment demand function. Consistently with the working of the input-output kernel that is shortly described in section 4, the investment demand function could be based on a flexible accelerator model of investment, in which industries show an ex-post adaptive behaviour by which they compare the existing capital stock with the desired capital stock related to the expected profit rate and to the user cost of capital, to determine the net investment decision.

Finally, as mentioned in the conclusion of the preceding section, in order to enrich the model's capability to capture demand-supply equilibration effects, equations relating to the scarcity of factor supply could be introduced. Several solutions are possible: the easiest and most stylised is certainly to resort to production functions exhibiting decreasing returns to scale. However, in the new economic geography strain of literature one seeks increasing, not decreasing returns. Functional forms should be chosen according to the economic insights they bear, not according to the desirability of their geometric properties. This highly stylised solution is therefore unviable, and a more explicit representation of factor supply scarcity is called for; since capital is short-term fixed, this feature would be easier to introduce in the labour market, where a labour supply equation relating wages to the unemployment rate could be estimated and included in the model. Note however that the econometric estimation is likely to be far less straightforward than the model coding, given the difficulty in detecting such wage-unemployment correlations in the historical data series of European countries, where the labour market has been historically far from an unfettered competitive market.

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Table 1. Own price elasticity parameters of energy, labour and imported materials (γ_{EE}, γ_{LL}, γ_{MM}, respectively) and cross price elasticity parameters for energy-labour, energy-imported materials and labour-imported materials (γ_{EL}, γ_{EM}, γ_{ML}, respectively)

NACE		γ_{EE}	γ_{LL}	γ_{MM}	γ_{EL}	γ_{EM}	γ_{ML}
15	Food products and beverages	0.0075	0.1033	0.0582	-0.0179	0.0211	-0.0320
		(2.37)	(12.29)	(3.30)	(-7.33)	(8.47)	(-4.52)
17	Textiles	0.0089	0.0256	0.0978	-0.0474	0.0385	0.0456
		(2.56)	(1.89)	(2.65)	(-6.69)	(7.18)	(4.43)
18	Wearing apparel; dressing and dyeing of fur	0.0042	-0.3040	0.1284	0.0191	-0.0273	0.1001
		(1.62)	(-9.33)	(5.26)	(4.57)	(-8.63)	(5.46)
20	Wood and of products of wood and cork	0.0053	0.1686	0.0002	-0.0139	0.0321	-0.0513
		(1.22)	(6.91)	(0.02)	(-1.62)	(5.45)	(-4.12)
21	Pulp, paper and paper products	0.0404	0.0867	-0.0952	0.0048	-0.0104	-0.0507
		(4.00)	(5.34)	(-2.65)	(0.51)	(-0.65)	(-3.17)
22	Publishing and printing	-0.0013	0.2000	0.0460	0.0166	-0.0101	-0.0456
		(-0.82)	n.a.	(3.61)	(5.62)	(-3.29)	(-4.36)
24	Chemicals and chemical products	0.0193	0.1600	-0.0477	-0.0510	0.0089	-0.0276
		(2.73)	n.a.	(-1.16)	(-5.77)	(0.73)	(-2.17)
25	Rubber and plastic products	0.0197	0.2000	0.0870	-0.0221	0.0081	-0.0798
		(6.01)	n.a.	(4.09)	(-4.51)	(1.61)	(-7.87)
26	Other non-metallic mineral products	0.0264	-0.0108	0.0454	0.0504	0.0049	-0.0842
		(4.46)	(-0.65)	(2.93)	(6.72)	(0.59)	(-7.46)
27	Basic metals	0.0125	0.1200	0.1231	0.0418	-0.0529	-0.0536
		(2.05)	n.a.	(5.68)	(7.31)	(-4.23)	(-7.33)
28	Fabricated metal products	0.0071	0.2100	0.0164	-0.0453	0.0236	-0.0131
		(3.00)	n.a.	(0.52)	(-10.41)	(7.52)	(-0.94)
29	Machinery and equipment n.e.c.	-0.0069	0.1482	0.1125	-0.0195	0.0181	-0.0917
		(-3.22)	(10.40)	(9.15)	(-3.41)	(3.94)	(-7.78)
31	Electrical machinery and apparatus n.e.c.	0.0056	0.0842	0.1700	0.0070	-0.0516	-0.0187
		(2.73)	(3.12)	n.a.	(1.37)	(-8.21)	(-0.97)
32	Radio, television and communication equipment	-0.0136	0.1500	0.0496	-0.0367	0.0494	-0.0728
		(-3.71)	n.a.	(4.20)	(-7.35)	(13.39)	(-10.33)
33	Medical, precision and optical instruments	0.0010	-0.0649	0.1601	0.0198	-0.0206	-0.1419
		(1.24)	(-7.63)	(23.98)	(8.39)	(-13.33)	(-28.52)
34	Motor vehicles, trailers and semi-trailers	0.0016	0.1600	0.1318	-0.0452	0.0129	-0.1218
		(0.40)	n.a.	(5.65)	(-8.51)	(2.24)	(-6.02)
35	Other transport equipment	-0.0020	0.0851	0.1323	0.0028	-0.0280	-0.1156
		(-2.15)	(1.56)	(1.78)	(0.45)	(-3.73)	(-2.16)
36	Furniture and manufacturing n.e.c.	0.0063	0.1815	0.0009	-0.0065	0.0030	-0.0736
		(2.35)	(7.78)	(0.02)	(-1.09)	(0.37)	(-2.95)
45	Construction	0.0009	-0.0693	0.0476	0.0303	0.0494	-0.1472
		(0.56)	(-2.85)	(3.55)	(5.57)	(12.42)	(-10.15)

* Note: t-Student values in parenthesis

Table 2. Own price elasticities of energy, labour, imported and domestic materials (ε_{EE}, ε_{LL}, ε_{MM}, ε_{DD} respectively)

NACE		ε_{LL}	ε_{EE}	ε_{MM}	ε_{DD}
15	Food products and beverages	-0.25370	-0.69117	-0.46173	-0.38373
17	Textiles	-0.62312	-0.71383	-0.36496	-0.26787
18	Wearing apparel; dressing and dyeing of fur	-2.03635	-0.75346	-0.27644	0.28172
20	Wood and of products of wood and cork	-0.00862	-0.79925	-0.83693	-0.56897
21	Pulp, paper and paper products	-0.36793	-0.29605	-1.23731	-0.88258
22	Publishing and printing	-0.04174	-1.06390	-0.46820	-0.47178
24	Chemicals and chemical products	-0.01602	-0.58455	-0.93388	-1.05452
25	Rubber and plastic products	-0.02018	-0.41882	-0.40613	-0.88652
26	Other non-metallic mineral products	-0.73283	-0.59121	-0.53707	-0.40103
27	Basic metals	-0.00166	-0.72799	-0.29602	-0.44794
28	Fabricated metal products	-0.02784	-0.64637	-0.70429	-0.77825
29	Machinery and equipment n.e.c.	-0.18527	-1.68274	-0.26822	-0.74743
31	Electrical machinery and apparatus n.e.c.	-0.40487	-0.42783	-0.06327	-0.43189
32	Radio, television and communication equipment	-0.07172	-3.37774	-0.49987	-0.91667
33	Medical, precision and optical instruments	-0.82021	-0.86849	-0.05547	-0.92680
34	Motor vehicles, trailers and semi-trailers	-0.00721	-0.85223	-0.23382	-1.03859
35	Other transport equipment	-0.40332	-1.18359	-0.23546	-0.86292
36	Furniture and manufacturing n.e.c.	-0.08554	-0.67709	-0.73908	-0.93122
45	Construction	-0.91226	-0.93315	-0.41123	-0.53189

* Note: Elasticity estimates for 2005

Table 3. Cross price elasticities of energy-labour, energy-imported materials and labour-imported materials (ε_{EE}, ε_{EM}, ε_{ML}, respectively)

NACE		ε_{EL}	ε_{LE}	ε_{EM}	ε_{ME}	ε_{LM}	ε_{ML}
15	Food products and beverages	-0.48743	-0.06942	0.94805	0.16659	-0.01801	-0.02631
17	Textiles	-1.02438	-0.12645	1.37638	0.16727	0.46981	0.43838
18	Wearing apparel; dressing and dyeing of fur	1.27652	0.10210	-1.10314	-0.05602	0.78465	0.53278
20	Wood and of products of wood and cork	-0.20099	-0.02918	1.17171	0.27905	-0.06882	-0.15752
21	Pulp, paper and paper products	0.29723	0.09594	0.06699	0.02249	-0.01003	-0.02530
22	Publishing and printing	1.33130	0.07197	-0.51193	-0.07432	-0.03633	-0.10579
24	Chemicals and chemical products	-0.66470	-0.16336	0.41445	0.11843	0.12823	0.10120
25	Rubber and plastic products	-0.31963	-0.03806	0.51036	0.06674	0.01181	0.00956
26	Other non-metallic mineral products	0.91929	0.25202	0.21615	0.11784	-0.12217	-0.26483
27	Basic metals	0.83104	0.36333	-0.52355	-0.09092	-0.04568	-0.00616
28	Fabricated metal products	-1.78632	-0.11565	1.31794	0.13825	0.17582	0.26249
29	Machinery and equipment n.e.c.	-1.67886	-0.05811	2.05920	0.09187	-0.09315	-0.11962
31	Electrical machinery and apparatus n.e.c.	0.95347	0.03879	-4.88030	-0.18399	0.21942	0.18301
32	Radio, television and communication equipment	-6.21179	-0.15933	9.04166	0.14786	0.02482	0.03102
33	Medical, precision and optical instruments	2.69922	0.06557	-2.15953	-0.07717	-0.13238	-0.24197
34	Motor vehicles, trailers and semi-trailers	-3.61382	-0.20860	1.41666	0.05692	-0.27535	-0.20276
35	Other transport equipment	0.52514	0.02211	-2.44338	-0.09185	-0.19255	-0.17464
36	Furniture and manufacturing n.e.c.	-0.01742	-0.00050	0.39835	0.03347	0.00467	0.00094
45	Construction	1.75357	0.11936	2.45244	0.52860	-0.37404	-1.19827

* Note: Elasticity estimates for 2005

Table 4. Cross price elasticities of domestic materials- imported materials, domestic materials- energy and domestic materials- labour (ε_{DM}, ε_{DE}, ε_{DL}, respectively)

NACE		ε_{DM}	ε_{MD}	ε_{DE}	ε_{ED}	ε_{DL}	ε_{LD}
15	Food products and beverages	0.08140	0.32145	0.01111	0.23054	0.09914	0.34112
17	Textiles	-0.19552	-0.24070	0.03929	0.36182	0.22097	0.27974
18	Wearing apparel; dressing and dyeing of fur	-0.18687	-0.20021	0.03186	0.58019	0.75318	1.14970
20	Wood and of products of wood and cork	0.19674	0.71545	-0.01101	-0.17140	0.04236	0.10668
21	Pulp, paper and paper products	0.57234	1.24012	-0.00299	-0.06818	0.13336	0.28202
22	Publishing and printing	0.12882	0.64831	0.00914	0.24454	0.00422	0.00611
24	Chemicals and chemical products	0.41212	0.71425	0.13381	0.83480	0.02821	0.05116
25	Rubber and plastic products	0.24634	0.32986	0.02330	0.22811	0.03466	0.04645
26	Other non-metallic mineral products	0.23252	0.68407	-0.09732	-0.54422	0.40239	0.60298
27	Basic metals	0.29255	0.39310	0.06676	0.42049	-0.08806	-0.31599
28	Fabricated metal products	0.15332	0.30350	0.05768	1.11470	-0.02698	-0.03238
29	Machinery and equipment n.e.c.	0.15028	0.29598	0.02943	1.30241	0.20681	0.33653
31	Electrical machinery and apparatus n.e.c.	0.06741	0.06419	0.09971	4.35461	0.08807	0.14660
32	Radio, television and communication equipment	0.29512	0.32097	0.01297	0.54786	0.12932	0.20621
33	Medical, precision and optical instruments	0.27029	0.37457	0.00932	0.32876	0.88428	0.88699
34	Motor vehicles, trailers and semi-trailers	0.27050	0.37966	0.08241	3.04939	0.22319	0.49116
35	Other transport equipment	0.30605	0.50178	0.06952	3.10167	0.30809	0.57359
36	Furniture and manufacturing n.e.c.	0.42101	0.70460	0.01517	0.29609	0.05279	0.08130
45	Construction	0.18879	1.08090	-0.12098	-3.27285	0.64021	1.16694

* Note: Elasticity estimates for 2005

Table 5. Estimates of own price elasticities of energy intensity (ε_{EE}) from 1995 to 2005

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
15	Food products and beverages	-0.63063	-0.63974	-0.65474	-0.67249	-0.65390	-0.62971	-0.66113	-0.66967	-0.67055	-0.67428	-0.69117
17	Textiles	-0.67967	-0.69959	-0.69960	-0.69590	-0.69387	-0.69464	-0.71354	-0.70112	-0.69939	-0.69901	-0.71383
18	Wearing apparel; dressing and dyeing of fur	-0.61024	-0.63434	-0.64683	-0.58801	-0.66487	-0.64592	-0.60680	-0.64827	-0.70045	-0.74123	-0.75346
20	Wood and of products of wood and cork	-0.77115	-0.76381	-0.77324	-0.77057	-0.76522	-0.78502	-0.77542	-0.78450	-0.79062	-0.79297	-0.79925
21	Pulp, paper and paper products	-0.11752	-0.23017	-0.26958	-0.37965	-0.22521	-0.16927	-0.23318	-0.25143	-0.29005	-0.27386	-0.29605
22	Publishing and printing	-1.10117	-1.10147	-1.09815	-1.10002	-1.07484	-1.09265	-1.09169	-1.08338	-1.05289	-1.07045	-1.06390
24	Chemicals and chemical products	-0.54312	-0.58566	-0.57661	-0.57380	-0.56927	-0.61210	-0.60196	-0.59938	-0.60241	-0.57241	-0.58455
25	Rubber and plastic products	-0.29542	-0.29028	-0.31153	-0.33115	-0.29562	-0.22700	-0.24322	-0.29372	-0.41756	-0.39533	-0.41882
26	Other non-metallic mineral products	-0.54877	-0.55366	-0.56934	-0.55829	-0.53740	-0.52595	-0.54948	-0.55575	-0.57975	-0.57023	-0.59121
27	Basic metals	-0.71819	-0.72695	-0.73038	-0.73502	-0.72793	-0.73424	-0.76180	-0.74811	-0.72291	-0.71317	-0.72799
28	Fabricated metal products	-0.60023	-0.67044	-0.66834	-0.66772	-0.66754	-0.60028	-0.60633	-0.61479	-0.65204	-0.63009	-0.64637
29	Machinery and equipment n.e.c.	-1.57201	-1.55791	-1.54328	-1.54763	-1.56213	-1.67580	-1.71364	-1.65196	-1.64620	-1.68803	-1.68274
31	Electrical machinery and apparatus n.e.c.	-0.50035	-0.56471	-0.57985	-0.55062	-0.54341	-0.31219	-0.32709	-0.43515	-0.47767	-0.40342	-0.42783
32	Radio, television and communication equipment	-2.58886	-2.58028	-2.43072	-2.40796	-2.36526	-4.93147	-4.09173	-3.67891	-2.98627	-3.23425	-3.37774
33	Medical, precision and optical instruments	-0.87586	-0.87500	-0.88655	-0.88686	-0.88484	-0.83717	-0.84339	-0.85583	-0.88151	-0.86370	-0.86849
34	Motor vehicles, trailers and semi-trailers	-0.86704	-0.88025	-0.87262	-0.87379	-0.85695	-0.86284	-0.85361	-0.86235	-0.87570	-0.85367	-0.85223
35	Other transport equipment	-1.11873	-1.13295	-1.11838	-1.11712	-1.14142	-1.18969	-1.17150	-1.15778	-1.15086	-1.16673	-1.18359
36	Furniture and manufacturing n.e.c.	-0.60914	-0.62697	-0.61893	-0.58522	-0.60903	-0.58033	-0.62413	-0.69387	-0.72516	-0.69261	-0.67709
45	Construction	-0.92720	-0.92443	-0.92449	-0.92486	-0.92597	-0.92820	-0.92373	-0.92661	-0.92807	-0.92518	-0.93315

Table 6. Estimates of parameters for embodied (ρ_{KE}, ρ_{KL}, ρ_{KM}) and autonomous (ρ_{tE}, ρ_{tL}, ρ_{tM}) technical change in energy, labour and imported materials, respectively

		ρ_{KE}	ρ_{KL}	ρ_{KM}	ρ_{tE}	ρ_{tL}	ρ_{tM}
15	Food products and beverages	-0.0099	0.0217	0.2763	0.0007	-0.0015	0.0031
		(-1.58)	(2.75)	(14.88)	(3.81)	(-4.71)	(7.44)
17	Textiles	0.0486	0.0200	0.2654	0.0007	-0.0005	-0.0040
		(8.96)	(1.16)	(6.10)	(2.69)	(-0.80)	(-4.30)
18	Wearing apparel; dressing and dyeing of fur	0.0049	0.1515	0.1901	-0.0008	0.0052	0.0085
		(1.08)	(6.40)	(3.14)	(-4.31)	(3.27)	(6.01)
20	Wood and of products of wood and cork	0.0093	0.0760	0.0293	0.0006	-0.0066	0.0023
		(1.21)	(5.08)	(1.67)	(2.99)	(-15.53)	(5.26)
21	Pulp, paper and paper products	0.1131	-0.0100	-0.0774	-0.0029	-0.0027	0.0038
		(6.04)	(-0.59)	(-2.10)	(-4.30)	(-4.22)	(3.74)
22	Publishing and printing	0.0165	0.0189	0.0341	0.0003	-0.0074	0.0011
		(4.99)	(1.66)	(2.17)	(1.70)	(-14.38)	(1.97)
24	Chemicals and chemical products	-0.0075	0.0409	-0.0334	0.0017	-0.0047	0.0012
		(-0.78)	(2.58)	(-0.86)	(4.68)	(-13.42)	(1.20)
25	Rubber and plastic products	-0.0070	0.0502	-0.0066	0.0003	-0.0036	0.0038
		(-0.84)	(3.03)	(-0.18)	(1.34)	(-10.75)	(4.44)
26	Other non-metallic mineral products	0.0047	0.0454	0.1307	-0.0002	-0.0028	0.0041
		(0.60)	(4.21)	(8.64)	(-0.64)	(-6.20)	(7.93)
27	Basic metals	-0.0310	0.1678	-0.0256	0.0011	-0.0068	0.0071
		(-1.71)	(16.29)	(-0.52)	(1.99)	(-20.41)	(6.77)
28	Fabricated metal products	0.0281	-0.0122	-0.0253	0.0002	-0.0020	0.0028
		(8.02)	(-0.75)	(-0.91)	(1.33)	(-4.76)	(4.95)
29	Machinery and equipment n.e.c.	0.0319	0.0350	0.0714	0.0004	-0.0058	0.0063
		(8.52)	(3.58)	(4.70)	(2.33)	(-13.79)	(12.62)
31	Electrical machinery and apparatus n.e.c.	-0.0111	0.0256	-0.1198	-0.0008	-0.0055	0.0039
		(-2.73)	(2.27)	(-5.35)	(-3.47)	(-4.45)	(2.98)
32	Radio, television and communication equipment	0.0254	0.1209	0.0385	0.0021	-0.0081	0.0000
		(6.75)	(10.25)	(1.44)	(3.88)	(-9.13)	(-0.01)
33	Medical, precision and optical instruments	-0.0011	0.0283	-0.0082	-0.0006	-0.0027	0.0061
		(-0.91)	(4.77)	(-0.94)	(-6.66)	(-8.34)	(14.49)
34	Motor vehicles, trailers and semi-trailers	0.0022	0.0512	0.0101	0.0011	-0.0088	0.0040
		(0.78)	(4.20)	(1.00)	(5.17)	(-17.32)	(4.68)
35	Other transport equipment	0.0135	0.1783	-0.1834	-0.0010	-0.0062	0.0058
		(1.98)	(3.89)	(-2.95)	(-1.69)	(-1.62)	(1.20)
36	Furniture and manufacturing n.e.c.	0.0042	0.0574	0.1256	0.0007	-0.0076	0.0055
		(0.85)	(4.89)	(7.00)	(3.95)	(-12.07)	(7.00)
45	Construction	0.0190	0.0399	0.0349	0.0005	-0.0046	0.0018
		(3.47)	(2.59)	(2.63)	(4.31)	(-9.48)	(5.41)

* Note: t-Student values in parenthesis